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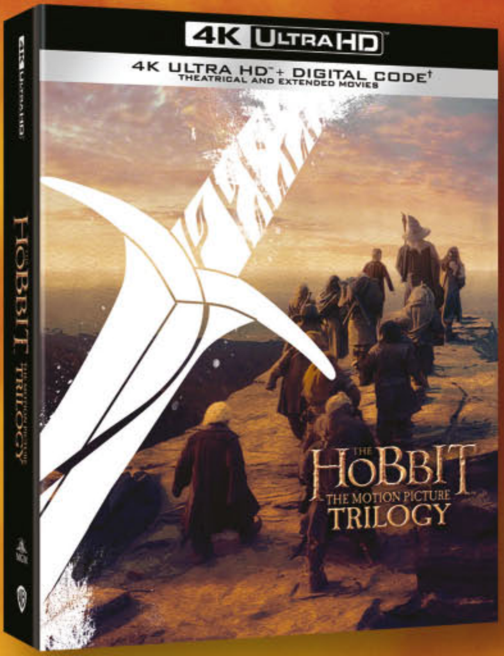
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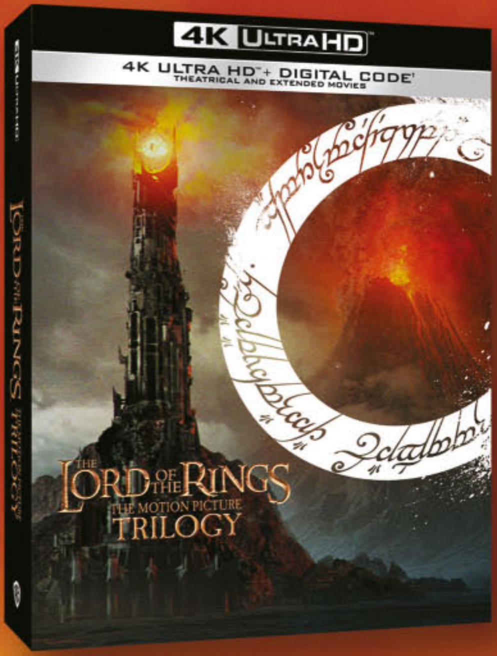
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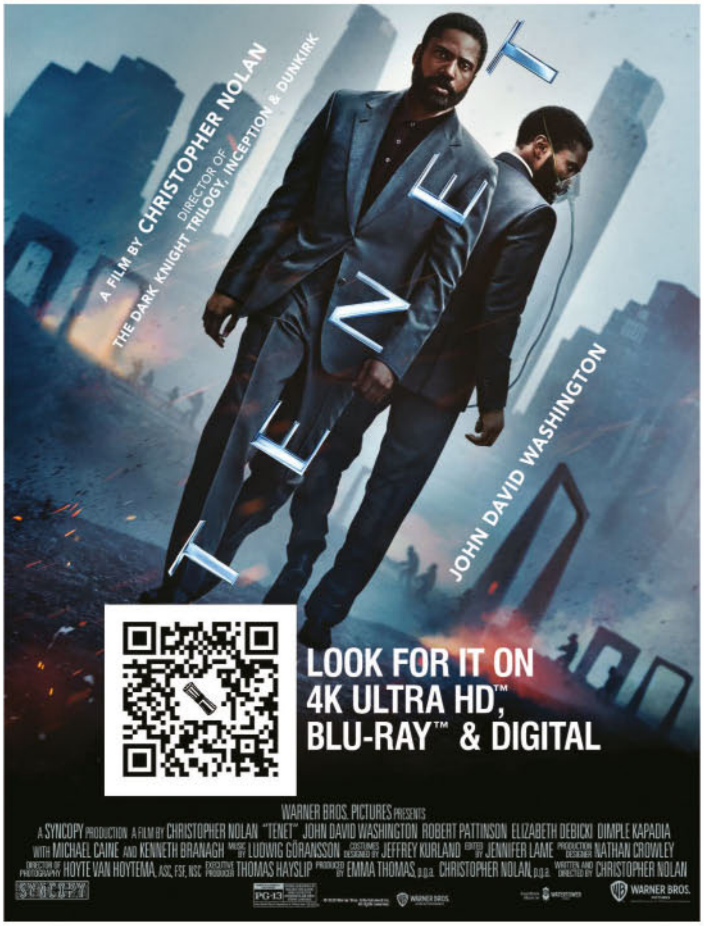
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## Zak Storey

# EVER ONWARD

**WELCOME** to the latest edition of *Maximum PC*. So first let's start with the good. This issue is jam-packed with a ton of features, content, and gloriousness to get your teeth stuck into. We've gone and compiled our favorite hardware from the last 12 months, handing out our awards in this year's prestigious Gear of the Year feature. We've also got Jarred back in the house to give us the lowdown on ray tracing, DLSS, *Cyberpunk 2077*, and what the future holds for graphics in general. Our man from Down Under, John Knight, gives us his fine interpretation of the history of computing, from analog all the way up to the modern era, while Ian Evenden has a fantastic piece on stripping out your old operating system and replacing it with a brand new Windows 10 OS install, all squeaky clean and shiny.

We've also got tutorials on how to tidy up your Windows desktop, and a huge seven-and-a-bit pages of build-it this issue, courtesy of our friends over at *Tom's Hardware* (and trust me you don't want to miss this one, as it's a true beauty—in fact you can spot it on the cover). And then of course we have oodles of reviews, from AMD's 6900XT GPU (which I seriously want myself) to Nvidia's RTX 3060 Ti, to a whole swathe of peripheral goodies. This issue is brimming with kick-ass content.

Sadly, however, this issue has also been a bit rough for myself and the team. Unfortunately Christian's had to take some considerable time out, and he won't be back full-time for around six to nine months as he battles some big health concerns. It is quite serious, but the prognosis is very good. I'm sure he'll have more to say on it next issue, since it's not really my place to explain it. But I just want to say that we're all behind him, and Future is supporting him as well, and we expect him to make a full recovery.

On top of that, my other half also managed to contract COVID-19 a few weeks back, and I got it as well. This put a huge dampener on my plans for this issue. In fact I had two epic builds lined up for it, ready to be shot in our photo studio, but unfortunately with Christian also out of action, no one could build them. Don't worry, they're penned in for next issue, and I'm super-excited for both of them. Thankfully the folks over at *Tom's Hardware* stepped in, and gave us an incredible liquid-cooled build log, complete with fresh content, and some new insight into their whole process, courtesy of Niels Broekhuijsen.

I'd also like to take this opportunity to welcome in some new blood to the team. Just while Christian is out, from next issue Sam Lewis will be joining the fold as a temporary staff writer, and bringing with him a whole swathe of epic content too. He's a dab hand at Photoshop and graphic design, loves VR, and is also fond of high-end audio.

I hope you enjoy the latest issue of *Maximum PC*. If you have any questions, queries, or subscription problems, please drop me a line at the email listed on the top left of the page.

As always, stay safe out there, and until next time!

Zak Storey

*Zak Storey is* Maximum PC's *editor and long-time staff member. He's been building PCs since he was 10, and is more than capable of butting heads with the biggest names in tech.*

↘ submit your questions to: comments@maximumpc.com

# THE NEWS

## Big Tech Under Fire

### Is there too much power in the hands of too few?

**LETITIA JAMES**, the attorney general for New York, has started two major anti-trust legal actions. One is against Facebook, which she claims has used its financial and marketing power to quash competition by buying smaller competitors before they can become rivals, and using market dominance to restrict competing services—in particular the $1 billion purchase of Instagram in 2012. The case has been joined by 47 other states. The second case is against Google, with claims it has “deprived consumers of competition that could lead to greater choice and innovation, as well as better privacy protections.” This case has been joined by 38 states.

At the same time the Federal Trade Commission has also launched a case against social media giant Facebook, highlighting its acquisitions of WhatsApp and Instagram in order to eliminate any serious threats to its virtual monopoly on social media. There's more: A case has been started in Texas against Google, alleging that it uses its market position to control online advertising. A similar suit from Colorado has attracted support from 36 states. The Department of Justice has also filed an anti-monopoly case against Google.

All these actions are from the last couple of months. Such legal actions are not new, and big tech firms have weathered many previous suits. Most of these cases will take many months or years to resolve, and will probably produce little tangible effect. On their own each one isn't enough to see either Facebook or Google seriously brought to account, let alone broken up. The worst case is probably a fine, and even billions won't touch them, or small changes in operation (do you remember when Microsoft had to give some options rather than just presenting Internet Explorer?).

While it is satisfying to see Google and Facebook held responsible in public to some degree, the only people these cases will leave richer will be the lawyers. However, such lawsuits are becoming increasingly regular, more focused, better supported, and more determined. The mood of the legislators is changing; these companies are great success stories, but the power they wield is clearly causing legislator concern. Companies in any line of business are combative, but there always comes a point when the competitive jostle becomes the aggressive stifling of rivals, and of choice. The tech industries have condensed into a very small number right across the board, from hardware to software. In some areas there is little competition at all. Whose maps do you use? Which search engine? Where do you watch videos? For most of us there is one main answer, and it is all the same company.

The legal pressure is building, and shows no sign of relenting. The cases are getting bigger and are attracting more state attorneys to support them. The DoJ, the FTC, and state attorneys are starting to join forces. At some point, somebody is going to lose in a meaningful way. Facebook looks like the weakest target—its dominance of social media has been so obviously at the expense of rivals. Amazon could possibly decouple Amazon Web Services, although it would have to be pushed hard: It is highly profitable. Google is a tougher customer for the moment, but won't be immune forever.

While legal cases have centered on the near-monopolies tech giants have built, other underlying concerns aren't far away. The internet may have started out as the place where individuals can find their corner, but it's since coalesced considerably. Governments are increasingly concerned with the amount of 'soft' power companies wield. Armed with comprehensive datasets on your likes and dislikes, it's a simple step to start pushing. Targeted advertising may seem innocuous, but it can become problematic. Never before have private companies known so much about our private life.

Still think Google isn't that big? Witness the recent outage. Google servers fell over for about 45 minutes, and it made headlines around the world. There are very few companies where a short break in internet services could possibly warrant that. No mail, no videos, no maps, and in some cases no lights, as smart homes stopped being so “smart.” Living without Google isn't easy. There are alternatives to what the big firms offer, but it requires compromises. Monopolies are not good for business. **–CL**

> “Governments are increasingly concerned with the amount of 'soft' power companies wield

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# ROCKET LAKE READIES

## NEW LEAKS EMERGE

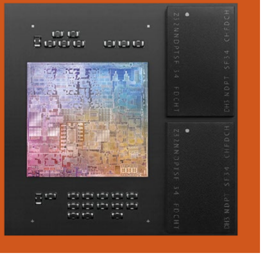
**INTEL'S 11TH-GENERATION ROCKET LAKE CHIPS** will be in our hands in March. We're starting to see unofficial leaks as engineering samples are distributed to the industry for testing. Early benchmarks have surfaced featuring the Core i9-11900K, an eight-core Rocket Lake with a reported base clock of 3.5GHz, and a maximum boost just shy of 5GHz. It apparently fairs well against an AMD Ryzen 7 5800X. The important thing is that there is a decent IPC bump of around 18 percent over previous Skylake-derived cores.

The Cypress Cove cores used in Rocket Lake chips are essentially 10nm Ice Lake ones shifted to a 14nm process, and combined with Tiger Lake's Xe graphics. We finally get a version of the Sunny Cove microarchitecture in a desktop chip, the first such new architecture in over five years. The IPC gains across the board, coupled with high base clocks, will keep Intel in the game. We also get PCIe 4.0 support, and four processor PCIe lanes for fast storage. The wait is nearly over. **–CL**

# APPLE GOING FOR 32 CORES

## New incarnations of Apple's ARM M1 chip

**APPLE HAS BIG PLANS** for its impressive new ARM M1 chip. Its first incarnation was as a hybrid with four high-performance cores, and four low-power cores. The next versions are in development, which will push the high-performance cores to eight, 12, and even 16, the last one destined for the MacBook Pro. These are due next spring. Beyond that is Mac Pro territory. Rumor has it that Apple is developing a full 32-core ARM chip for its workstation, which currently runs 28-core Xeon W chips. Apple isn't just ditching Intel either: The AMD GPUs are due to be replaced by Apple's GPU design, which we first saw integrated into the M1 chip. We can expect everything from 16-core mobile models, up to 28-core bad boys, all due next year (give or take). Meanwhile, Apple is also developing its own 5G modems; it looks as if Apple is serious about being largely self-sufficient in silicon by 2022. If those high-end chips can threaten x86 Intel/AMD desktop designs things could get interesting. **–CL**



# Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

## TRIUMPHS

✓ **EXPENSIVE PLUMBERS**
A new record for a collectible game has been set: $156,000 for a mint condition early *Super Mario Brothers 3* cart for NES.

✓ **MICROWAVE DRIVES**
Toshiba will ship its first microwave-assisted magnetic recording drive (MAMR), a nine-platter 18TB drive, next spring.

✓ **CHEAPER MEMORY**
Production of 3D NAND is ramping up fast; expect prices to fall by 10 to 15 percent soon.

## TRAGEDIES

✗ **PUBLIC FISTICUFFS**
After Apple decided to let users decide whether to share data, Facebook and Apple have been having a public row about it.

✗ **ALMOST SUCCESS**
SpaceX's recent SN8 Starship rocket test was nearly perfect, apart from the crash landing.

✗ **PR FAIL**
Intel tried to convince the world that AMD's mobile chips lose up to 48% performance running on battery power. It's not true.

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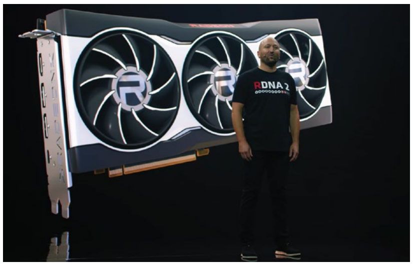

# LAUNCHED, BUT NOT AVAILABLE

## Elusive graphics cards

**RECENTLY** there have been a lot of lovely new graphics cards from Nvidia and AMD, each with new GPU architectures setting performance records. The trouble is actually getting hold of one. The "unexpectedly" high demand (really?), coupled with production problems have made this a frustrating time to build a gaming rig. Nvidia's GeForce RTX 3090 and RTX 3080 cards are all over the media but not the shelves, even online. Speculators bought everything they could to resell at a profit. The RTX 3090 is officially $1,499, but the average resale price is $2,250. This isn't helped by the ending of production of RTX 2000 series cards, the supply of which seems to have dried up.

Samsung, which makes the 8nm GPUs for Nvidia, has been having "issues" with yield (the number of usable chips from a wafer), and is struggling to make reliable die. There are rumors of some production being moved to TSMC to compensate.

Supply of AMD's new RX 6000-series cards isn't much better. It uses 7nm wafers from TSMC, which has its hands full making Ryzen processors, console chips, phone chips, and much more. The profit margins on the processors are higher, and each card uses a lot of silicon. Tight supply of GDDR6 memory doesn't help either company, given how much the high-end cards need.

Things are expected to calm down, but not until toward the end of 2021, when chip yields stabilize and serial production can get going. Until then you'll either have to be lucky or pay over the odds. Meanwhile, the cards have become attractive to thieves. In China 40 boxes of RTX 3090 cards—about 220 cards—were stolen from the MSI factory in what was probably an inside job, given the amount of security the factory has. The haul has a value of about $330,000. A reward for information has been made, but the thieves will have no problems shifting the loot. 2020 may have seen the launch of the next-gen graphics cards, but it'll be late 2021 before we can readily buy them. **–CL**

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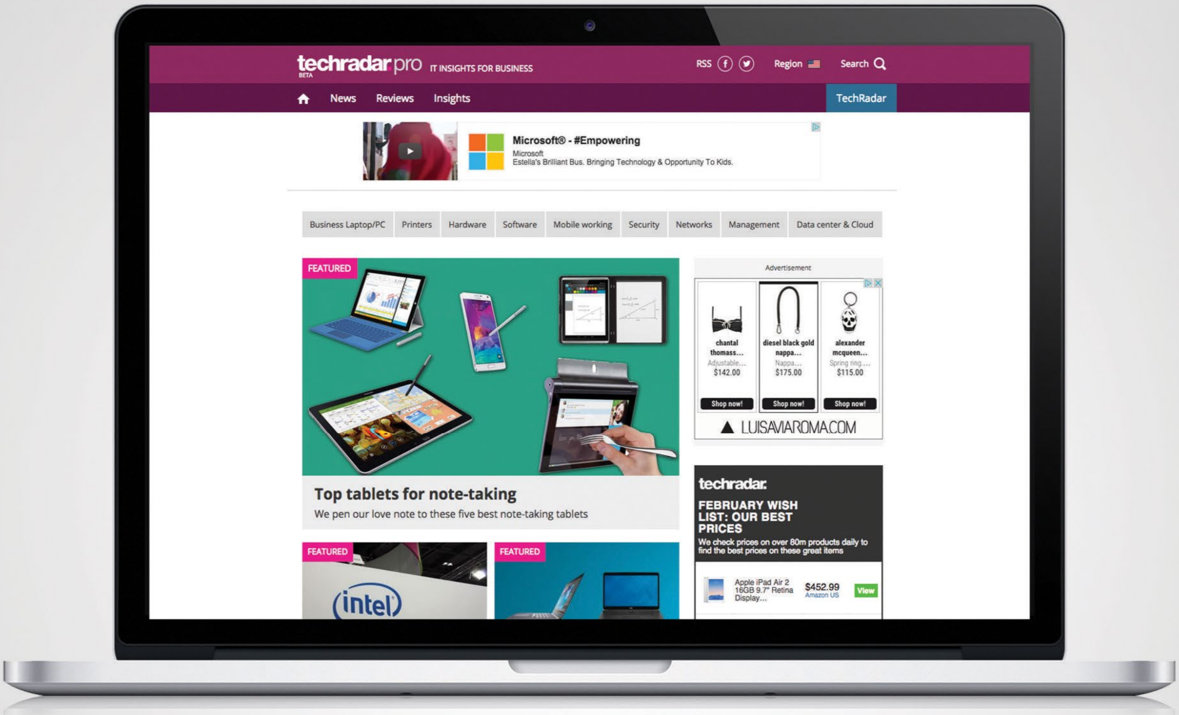
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## New Year, New GeForce Cards

**THE LAUNCH OF THE GEFORCE RTX 3080 TI** was set for January, but has been pushed back to the end of February. Why? Well demand for the existing cards is high, and while AMD's cards are good, they aren't good enough to make Nvidia rush out anything, particularly as it can sell every $1,499 RTX 3090 it can make. The GeForce RTX 3080 Ti sits squarely between the RTX 3080 and RTX 3090. It has the same number of cores as the RTX 3090—10,496—but carries 20GB rather than 24GB of GDDR6X memory sitting on a 320-bit rather than a 384-bit memory bus, so the bandwidth drops from 936GB/s to 760GB/s. It's expected to go for $999, neatly in the middle of its siblings at $1,499, and $699.

The GeForce RTX 3060 is still on track to appear in January though. This will come in two versions: 12GB, and 6GB—the smaller version effectively a re-branded RTX 3050 Ti. There will be more cards to follow too; we've got the RTX 3070 Ti and RTX 3050 to look forward to, as witnessed by support for them in the new release of AID64 (the system information and diagnostic app). Other reports say Nvidia won't use numbers below 3060, though, so we shall see. The high-end cards get all the publicity, and why not? We love them, but the more modest cards are where the numbers are. But given the limited supply of GPUs that's likely to continue well into next year, Nvidia's best tactic is to sell each one in a high-end card. It also helps manage the yield on the 8nm GPUs silicon Samsung is making for Nvidia. **–CL**

## Boston Dynamics Sold

The makers of quirky walking robots, Boston Dynamics, has been sold to Hyundai for $921 million. The company was born out of an MIT project in 1992, and has been working on robots ever since, although it has only just started selling its first commercial bot, the Spot, a dog-like quadruped. The company was owned by Softbank, which bought it from Google in 2017. Hyundai will be a good fit for Boston Dynamics—the company's previous owners (especially Google) didn't really know what to do with it. Hyundai is a major player in robotics, and Boston Dynamics is the world leader in walking robots. If you haven't seen the company's robots in action, they are amazing. **–CL**

## New Bitcoin High

Bitcoin has reached a new all-time high of over $23,000, beating its previous spike in December 2018 of just under $20,000, making the whole stack worth $428 billion. This makes the first time Bitcoin was used to pay for something, 10,000 coins for two pizzas, look like a poor deal—that's $115 million each now. Bitcoin is notoriously volatile: At the start of 2020 it was worth around $7,200, and even dipped to under $5,000 in the spring. Despite technical issues, numerous frauds, and exchange bankruptcies, there are over 110 people that hold over 10,000 coins each. Bigger investors will help stabilize values in the long run, but it remains worryingly susceptible to the winds of fortune. **–CL**

Cyberpunk
2077

## CYBERPUNK 2077'S DISMAL LAUNCH

### Reality did not match the expectations

**CYBERPUNK 2077** from CD Projekt Red was a hotly anticipated AAA game. Development started in 2012, but it missed four release dates this year. It sold 8 million pre-order copies, and the buzz was palpable. Then the wheels came off the bus. There were bugs, poor performance, and a host of technical issues we won't go into here (although we do on PG15). Patches followed quickly—it received a whopping 43.5GB patch before release, and another on day one. Patches aren't uncommon in games, where discs have to be prepared weeks in advance, and the internet makes distribution after release easy. However, these patches were well beyond simple tweaks.

The biggest gripe was the graphics, which had looked so good in the previews. Those playing on PS4, and Xbox One were disappointed by a blurry world. This helps explain why all previews were done on PCs at least. Add the bugs, and you can guess the reaction. The PC versions proved more stable and better-looking. But the beautiful, atmospheric world of Night City takes a lot of computational power. If you want to game in 4K you'll need something special in the graphics slot—even the mighty GeForce RTX 3080 can't break 40fps. The poor reactions caused CD Projekt Red stock to drop 40 percent. It issued an apology of sorts, which said that it should have "paid more attention to making the game play better on PlayStation 4 and Xbox One".

*Cyberpunk 2077* is ambitious, which really stretches the current hardware, and clearly wasn't finished. They will fix it, but the mess hasn't done CD Projekt Red any favors. What is really annoying players is that the developer knew full well that it wasn't ready, and released it anyway. **–CL**

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**Jarred Walton**

## TECH TALK

# Cyberpunk 2077: Time For An Upgrade

**THE MOST ANTICIPATED GAME** for years, *Cyberpunk 2077* provides insight into all the modern complexities of game development. Hundreds of individuals worked for years to bring Night City to life, and while I appreciate much of the end result—despite the bugs and glitches—it's clear developer and publisher CD Projekt Red made serious mistakes.

The company admitted as much, and in an unprecedented move, the game was pulled from the PlayStation store, and everyone who purchased it was offered a full refund. Microsoft likewise offered full refunds for Xbox One players. The PC release running on modern hardware still has some issues, but nothing so far that I've considered fully showstopping. Maybe I got lucky, but more likely is the fact that I'm drastically exceeding the official minimum recommended specs.

CD Projekt Red lists a relatively ancient Core i5-3570K or FX-8310 CPU, 8GB RAM, and a GTX 780 with 3GB of VRAM as the minimum hardware requirements. You'll really want a newer GPU, and the GTX 1080 barely breaks 60fps at 1080p medium. Along with a decent graphics card, though, you'll want a better CPU as well. The i5-3570K is a four-core/four-thread Ivy Bridge CPU, never mind the AMD Bulldozer chips that never quite lived up to expectations. Bottom line: Things are going to be much worse trying to run a complex game like *Cyberpunk 2077* on old hardware.

Night City is a sprawling metropolis, and you can drive from one end to the other without a single loading screen. Scaling that down to run on CPUs that launched over eight years ago is a recipe for disaster, but things really went wrong with the previous-gen consoles. CD Projekt Red knew the game had problems on the Xbox One and PlayStation 4, but the holiday season was calling. However, it wasn't ready, and I'm not sure it's ever going to be a good experience on those consoles.

**Turning Night City into a thriving metropolis requires a powerful CPU.**

AMD's Jaguar cores sit at the heart of the Xbox One and PS4. Jaguar was already slow even when it was new. It was designed to be a power-efficient architecture, with speed very much a secondary concern. Each Jaguar core is relatively simple, dispatching up to two instructions per clock. Third-gen Intel cores, in contrast, can do four instructions per core. Add in larger caches, better branch prediction and other elements, and basically Ivy Bridge is at least twice as fast as Jaguar at the same clocks. Even the updated Xbox One X and PlayStation 4 Pro only clock in the low 2.1-2.3GHz range. Third-gen Intel CPUs run at 3.0-3.9GHz, while modern AMD and Intel chips can hit 5GHz, dispatch up to six IPC per core, and have six to 16 cores.

While the previous-gen consoles have OK GPUs (basically RX 570 level), the eight Jaguar cores are a major bottleneck in *Cyberpunk*. Core i9-9900K is easily five times as fast as the console Jaguar CPUs, sometimes more. Which already sounds bad, and then you realize that the i9-9900K ends up limiting performance in *Cyberpunk 2077* to around 110fps. 20 percent of that? Yup, we're looking at fps in the low 20s, or worse. The PlayStation 5 and Xbox Series X are also eight-core/16-thread CPUs, and that was clearly a target for the game.

It's going to be interesting how things progress. CDPR is working hard on fixing performance and bugs for both PCs and consoles. Will that eventually make for a playable 30fps experience on the PS4 and Xbox One? Possibly.

*Jarred Walton has been a PC and gaming enthusiast for over 30 years.*

© CD PROJEKT RED

# DOCTOR

THIS MONTH THE DOCTOR TACKLES…

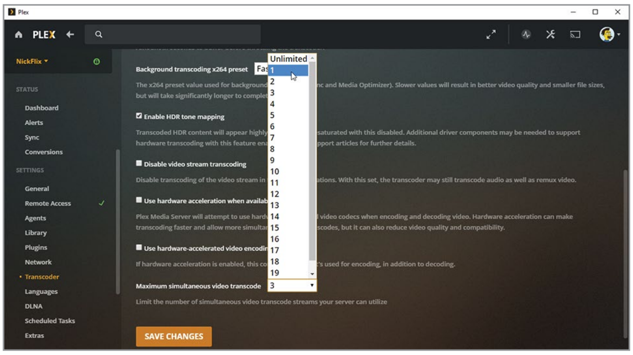
## > Video Transcoding
## > Locked Out Of BIOS
## > Failing USB Ports?

### Plex Transcoding

I recently opened up my Plex server running on a QNAP TS-251+ to a few friends to discover that transcoding does one of two things: If I enable hardware transcoding, the video frequently looks blocky and pixilated, but I can stream to multiple clients with no problems. But if I disable it, only one person can watch a transcoded stream without overwhelming the server. What can I do to improve the quality over hardware transcoding? **–Phil West**

**THE DOCTOR RESPONDS:** The problem here is your QNAP's Celeron J1900 processor. Although it supports hardware transcoding through QuickSync, the processor's onboard GPU is based on the old Ivy Bridge generation of Intel HD graphics. These are known for the poor quality of their transcodes, so the only way around this is to either minimize or eliminate transcoding from your machine (dig out your copy of *Maximum PC Dec 2019* for a guide to doing just that) or upgrade your NAS.

You could opt for QNAP's TS-251D series ($300 with 4GB RAM), which is powered by a dual-core J4025/J4005 Celeron processor sporting Intel HD Graphics 600—it's this 6th-generation chip where QuickSync finally delivers good-quality hardware-transcoded video. Or build your own NAS-like system around an embedded micro-ITX board sporting an Intel Gemini Lake processor, such as ASRock's J5040-ITX ($119.99). The Pentium Silver J5040 is quicker than the J4025 Celeron processor, and sports slightly more powerful graphics (Intel UHD Graphics 605) but is similarly low-powered (just 10 watts) and fanless, making it suitable for 24/7 use with little noise.



Background transcoding x264 preset Fas

The x264 preset value used for background … nc and Media Optimizer). Slower values will result in better video quality and smaller file sizes, but will take significantly longer to complet…

☑ Enable HDR tone mapping

Transcoded HDR content will appear highly … saturated with this disabled. Additional driver components may be needed to support hardware transcoding with this feature ena… pport articles for further details.

☐ Disable video stream transcoding

Disable transcoding of the video stream in … ations. With this set, the transcoder may still transcode audio as well as remux video.

☐ Use hardware acceleration when availab…

Plex Media Server will attempt to use hard… video codecs when encoding and decoding video. Hardware acceleration can make transcoding faster and allow more simulta… scodes, but it can also reduce video quality and compatibility.

☐ Use hardware-accelerated video encodin…

If hardware acceleration is enabled, this co… 's used for encoding, in addition to decoding.

Maximum simultaneous video transcode 3

Limit the number of simultaneous video transcode streams your server can utilize

**Hardware transcoding works best with later-generation graphics.**

© PLEX

The board's specs state that the J5040-ITX only supports up to 8GB RAM, yet ASRock's own memory compatibility chart (https://bit.ly/MPCASrock) reveals it can work with up to 32GB RAM. A pair of 4GB DDR4 SODIMMs costs around $40, but you may want to opt for 16GB to free up plenty of RAM for the GPU.

You'll also need a suitable mini-ITX case to house it all, and given the J5040-ITX has four onboard SATA connectors, why not source a compact model with removable drive bays, such as IN WIN IW-MS04 with 250W PSU ($161 on www.newegg.com)? There's no software cost involved—while the board will run Windows, we recommend you go with Ubuntu Server, as the Windows version of Plex limits hardware transcodes to just two at any one time.

The QNAP has the slight advantage on price, coupled with the fact you'll be running a familiar operating system, but the custom build gives you the advantage of a beefier processor, plus support for more RAM and more drives.

### BIOS Lockout

I have an ASUS Q324UA laptop that was given to me by my son after he could no longer access the BIOS. Since he travels for his work, he thought it wise to set a BIOS password. No problem for a while. During some work to upgrade his desktop, he was using the laptop to go online for instructions. After completion of the project, he shut down the laptop, never to access it again. Somehow, the password is corrupt? Maybe he forgot? We have tried every combination we can think of. I also read that a Microsoft Windows update corrupted the Administrator password. ASUS declined to comment on that.

ASUS Support tells me there is no "back door." ASUS factory repair in Georgia will replace the motherboard for $600 plus labor. It appears the BIOS on this machine is on an EPROM and there's no way to change it. This seems to be the consensus online.

Do you have a remedy? Can the BIOS be reset, or do I now have an expensive paperweight? **–Jim Roebuck**

↘ submit your questions to: doctor@maximumpc.com

**THE DOCTOR RESPONDS:** Your son has learned a valuable lesson about the shortcomings of setting a BIOS password, Jim! They can stop working for no logical reason, and ultimately do little to protect your machine—a determined thief could simply remove the hard drive and access any sensitive data directly. A better way to secure a laptop going forward is by using BitLocker to encrypt the entire drive, which protects the drive contents as well as access to Windows. Store the password somewhere safe—try a secure note in Bitwarden for example—so it's never forgotten.

There's one thing ASUS laptop owners can try to bypass the BIOS password, depending on your laptop model. First, when the password prompt appears, try pressing Alt + R, which should bring up an "Enter Rescue password" box with the date on it in YYYY/MM/DD format. Visit www.biosbug.com/asus on a working PC and enter that date into the box, then click "Send Request." After a short pause, a series of letters and numbers will appear, which you should enter as the rescue password to hopefully unlock the laptop. Then, press F2 to go into the BIOS to navigate to the "Security" tab and remove or change the password.

Jim had already tried this workaround—this particular ASUS model didn't support the recovery password option. Ultimately there appears to be no way to reset the BIOS to remove the password, but we found a cheaper alternative to ASUS's $600 solution: purchase a refurbished motherboard for $170 on www.newegg.com (search "Asus Q324UA Laptop Motherboard") and then swap out the old mobo for new, following iFixit's guide (https://bit.ly/MPCifixit). It's an expensive fix, but it's cheaper than replacing an otherwise-serviceable laptop.

## CPU Fan Error

Any idea why this happens? I have a water-cooled system (HydroLux Level 3) that keeps my system (ASUS ROG Rampage V) pretty much at a consistent 25 degrees Celsius, yet it's started throwing up a CPU fan error when I switch on, halting the boot sequence. If I press Ctrl + Alt + Del to restart, then it launches Windows fine.

**–D Dominguez**

Water pumps can trigger errors if plugged into the CPU_FAN header.

© WWW.DIGITALSTORM.COM

**THE DOCTOR RESPONDS:** This is quite common with water-cooled systems on mobos that don't have a specific water pump cooler header on them. When you plug your water pump into the CPU fan header, it's unable to provide enough sustained power to run the pump at full speed, which triggers the error. This is a false positive, and you can either continue to ignore it or enter your BIOS to instruct your PC to ignore the CPU fan speed in its monitoring section, and the error will vanish.

In the case of your ASUS ROG Rampage V, browse to "Monitor → CPU Q-Fan Control (Auto)" and look for a "CPU Fan Speed Low Limit" setting—change this to "Ignore," which should stop the alert appearing on startup. Some ASUS ROG Rampage boards provide a W_PUMP header, so if you own one of these boards, you should power down your PC and check that all the fan connectors are plugged securely into the correct sockets. If you've got a regular fan plugged into the CPU_Fan header, check this is running OK as it'll be responsible for the error—it may need cleaning out, or may be a symptom that the fan's starting to fail as it can't spin fast enough to satisfy the BIOS.

## USB Mouse Disconnects

I'm having some problems with the USB ports on the back of my system into which are plugged my mouse and keyboard. While casually playing some video games, both the mouse and the keyboard disconnect, even though they are still connected to the back of the motherboard, and the only way to get it working is to do a full reset of my computer. I'm running a Ryzen 7 3700X on an ASUS ROG STRIX B450-F GAMING mobo, 16GB RAM and 500GB M.2 drive. Can you explain the cause of the disconnect?

**–CakeGamer21**

**THE DOCTOR RESPONDS:** There are several questions here that need answering: First, are you hearing the classic USB disconnect sound indicating the keyboard and mouse are being disconnected, or do they simply stop working? If it's the latter, the problem may be Windows locking up, or it may be linked to the game. Does it happen elsewhere on your system?

If the problem is an intermittent one with no obvious reasons behind it, then it may be a hardware issue. You could try a different keyboard and mouse in your PC, but the chances of both failing in the same way seem remote. Instead, try plugging them into different ports to see if that fixes the problem; if it does, the ports in question may be failing. Given the ROG STRIX B450-F has plenty to spare (eight at the back of the mobo alone), this workaround on its own could be acceptable.

If the problem affects all USB ports, make sure your UEFI/BIOS is fully up to date (choose the non-beta version), as well as your motherboard chipset drivers. Next, try disabling the "USB Selective Suspend" option—press Win + R, type "powercfg.cpl" and hit Enter. Click "Change plan settings'"next to the selected plan, followed by "Change advanced power settings." Expand "USB settings → USB selective suspend setting," and set it to "Disabled" before clicking "OK."

If you're still plagued by the disconnects, open Device Manager and expand the "Universal Serial Bus" controllers section—double-click each USB Root Hub in turn, switch to the "Power Management" tab and untick "Allow the computer to turn off this device to save power," before clicking "OK." Double-check the options haven't been ticked for your mouse and keyboard too (although they're more likely to have been grayed out and the device allowed to wake your PC).

Still no luck? There's the possibility of Registry corruption, which results in duplicate entries for your mouse and/or keyboard being created in Device Manager. You can verify this is the case using Nirsoft's free USBDeview tool (www.nirsoft.net/utils/usb_devices_view.html)—download, extract, and run the x64 version. If your mouse appears multiple times in this list, removing all the entries then rebooting may temporarily solve the problem.

Finally, if the problem only occurs while gaming, it may indicate that your PSU is struggling to meet the demands being made of it when your system is under load. Now may be a good time to consider upgrading or replacing it. But before doing so, if the problem only occurs in one game, it's likely that the problem is caused by that, so visit user forums and support pages to see if others have reported similar problems.

**2021 AWARDS**

# GEAR of the YEAR

**VERDICT 9 KICK ASS!**

**IT'S THAT TIME AGAIN,** *Maximum PC*'s Gear of the Year awards, where we take a look at the very best hardware to have launched in the last 12 months (that we've got hands-on with) and give you the lowdown on exactly where you need to be dropping your hard-earned cash.

It's been a tough 12 months in the world of tech, but we've seen an abundance of new products launch in that time. From new processors to GPUs, monitors, SSDs and more, it's been an incredible year. Although we may have been stuck inside a lot more than we'd like, the tech must always flow, and thanks to the perpetual drive of this fantastic industry, there's a ton of new products that you should definitely keep your eye on.

Now not everything has made the cut; you'll notice that Intel still hasn't managed to quite sink its teeth into our CPU list just yet, nor has AMD managed to supplant Nvidia for the GPU crown. It's worth noting, however, that both of these companies have released some fantastic products in these segments, and although they're not featured on this list, it was a darn close race—and if anything it makes it even more exciting for the year to come. Nothing breeds performance increases like competition. Anyway, let's get down to it! **–THE MAXIMUM PC TEAM**

**SPECIAL MENTION**

## Raspberry Pi 400

**The Raspberry Pi foundation continues to amaze us year on year. And with its latest Pi 400, we thought it was right to give it a special mention, despite not winning our coveted Kick Ass award (check out the full review on PG 89)—after all this thing is awesome. It's basically a Pi 4 redesigned to fit into this stellar keyboard frame, complete with a ton of ports, and weirdly it actually performs better because of it.**

**Getting access to a super-small form factor computer like this for your work or home office for $70 is genuinely impressive, and if you'd told us this would be possible 10 years ago, we would have laughed out loud. The only downsides? Well GPIO access is awkward as heck.**

● ***$70*** ● ***www.raspberrypi.org***

*Reviewed: Vol. 26, No. 2, Page 89*

© RASPBERRY PI FOUNDATION

**KEY**

VERDICT 9 KICK ASS!

**WINNER**

VERDICT 9

**RUNNER UP**

CPU

VERDICT
9
KICK ASS!

## AMD Ryzen 9 5900X

It's perhaps no surprise that AMD has snatched the top spot when it came to processors. Its Ryzen 5000-series chips have finally supplanted Intel's hold on the gaming crown. On top of that, thanks to some intuitive cache design combined with a core-complex rejigging, Team Red finally managed to quash a lot of the memory latency problems that have plagued Zen chips since its original debut back in 2017.

Our chip of choice for this series is the Ryzen 9 5900X. It may not be the flagship part, but with a bank of 12 cores, 24 threads, and an epic price point, it makes it one of the best processors money can buy right now.

● ***$550*** ● ***www.amd.com***
*Reviewed: Vol. 26, No. 1, Page 72*

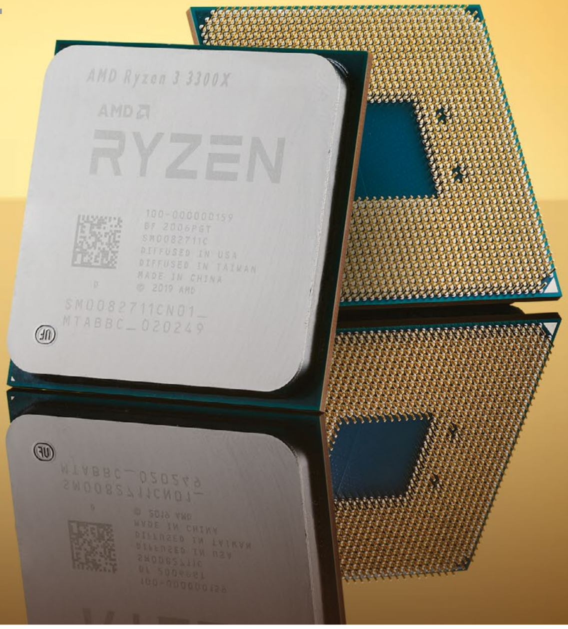
VERDICT
9

## AMD Ryzen 3 3300X

Hot on the heels of the Ryzen 9 5900X is the far more affordable Ryzen 3 3300X. Although this chip is absolutely last gen by comparison, it was the first 3-series chip to feature the Zen 2 architecture, complete with support for PCIe 4.0, and X570-series motherboards.

On top of that it has four cores, eight threads, and a full bank of PCIe lanes to max out your graphical performance at the expense of integrated graphics. This makes it a super-budget gaming processor, with solid performance—not too dissimilar from the Core i5s of old.

● ***$130*** ● ***www.amd.com***
*Reviewed: Vol 25, No. 9, Page 64*



PRICES CORRECT AT THE TIME OF PRINTING

GPU

VERDICT 9 KICK ASS!

## Nvidia GeForce RTX 3080

Here we have the king of graphical processors, the Nvidia GeForce RTX 3080, and the second generation of Team Green's ray-tracing behemoths. The 3080 saw a price drop compared to its predecessors, and a bevy of new improvements, including a redesigned cooler, expanded 8nm manufacturing process, and rekerjiggered architecture.

With more CUDA cores and memory, and more tensor and ray-tracing cores, the RTX 3080 makes 4K 60fps not only feasible but easily achievable — ours hit 100fps on average over 10 separate games. On top of that it obliterated the RTX 2080 Ti at half the cost. The downside? They sell like hot cakes.

● ***$799*** ● ***www.nvidia.com***

*Reviewed: Vol 25, No. 12, Page 68*

RTX 3080
GEFORCE RTX

VERDICT 9

## Nvidia GeForce RTX 3060 Ti

Two Nvidia cards in one round-up? Darn right. AMD put in an impressive display with its AMD Radeon RX cards, but it fell behind on overall performance, and so the RTX 3060 Ti claims the crown of best budget GPU.

Do you own an Nvidia RTX 2080 Super? Because if you do, that's what this card performs like. It's scarily effective. Take this subtle $399 GPU into the world of *Cyberpunk 2077* at 4K and enable DLSS, and you can easily hit that 60fps frame rate, no sweat. Its only drawback? Stock once again—something Nvidia is looking to rectify in Q1 of this year.

● ***$399*** ● ***www.nvidia.com***

*Reviewed: Vol. 26, No. 2, Page 76*

SSD

## Samsung 980 PRO 1TB M.2 PCIe 4.0 SSD

VERDICT 9 KICK ASS!

It was only a matter of time until Samsung finally unleashed its PCIe 4.0 drive, and boy was it a show. Although late to the party by well over a year, the South Korean giant debuted the 980 PRO at some ridiculously cheap price points and with unparalleled read/write performance too, topping out at over 7,000 MB/s sequential reads on this 1TB model.

What's better still is that this doesn't drop off too dramatically the further down the capacity stack you go. 500GB sits pretty at 6,900 MB/s, and the 250GB variant managed a slice at 6,400 MB/s, and at an impeccable $90 as well. We're still a fair way away from the likes of PCIe 4.0's full bandwidth capacity just yet, but this is absolutely a big step in the right direction.

● ***$230*** ● ***www.samsung.com***
*Reviewed: Vol 25, No. 13, Page 85*

## Corsair MP400 2TB M.2 PCIe 3.0 SSD

VERDICT 9

From PCIe 4.0 down to PCIe 3.0, the Corsair MP400 2TB drive (reviewed this very issue on PG 85) is by far our favorite PCIe 3.0 drive of the year. Really it's just incredible how well this thing performs for the price.

At $245 this 2TB behemoth packs in sequential reads at 3,400 MB/s and writes at 3,000 MB/s. And it's not too shabby at random 4Ks either—in fact it even beats out Samsung's impressive 970 Evo Plus. If you're still on a PCIe 3.0 platform, or are just looking for a solid and dependable games and media drive for your new Ryzen system, for the money the MP400 2TB is one of the best, and what QLC should have been to begin with.

● ***$245*** ● ***www.corsair.com***
*Reviewed: Vol. 26, No. 2, Page 85*

MONITOR

VERDICT 9 KICK ASS!

## ViewSonic Elite XG270QG

ViewSonic's Elite XG270QG is everything you could ever want from a monitor. Its clean, subtle gaming design is mixed with a specs list that'll make anyone drool, cementing its place as our favorite monitor of the year. It's not the most extravagant—it's just a 27-inch panel, with a 2560 x 1440 resolution, and a 165Hz refresh rate—but it's the trickery going on underneath that really makes it a king of screens, and it all comes down to that panel.

Yep, we're talking about the Nano IPS color tech that is at its heart. With unprecedentedly vibrant yet accurate 10-bit color, this thing can produce an incredible 98% of the DCI-P3 color spectrum. It also features G-Sync, sight shields and a handy integrated headphone stand.

● **$560** ● ***www.viewsonic.com***

*Reviewed: Vol. 25, No. 6, Page 70*

VERDICT 9

## Philips 279C9

Second place this year goes to the Philips 279C9. This incredible 4K IPS monitor is just leaps and bounds ahead of the competition. With a slick design, impressive 4K panel, remarkable color, immense pixel density, and USB Type C hub, it's ideal for any professional home-worker looking to spruce up their office.

It's not flawless—there are some caveats for this type of screen. It's not really a true HDR monitor, nor does it have some of the more sophisticated gaming tech that our winner has, but nonetheless, for those not interested in that particular area of the PC hobby, it's perfect.

● **$500** ● ***www.philips.com***

*Reviewed: Vol. 26, No.1, Page 80*

LAPTOP

VERDICT 9 KICK ASS!

## Razer Blade Pro 17

Razer has made a name for itself over the last few years as one of the best laptop manufacturers out there, and its latest series of Blade notebooks really does take the crown. The Blade Pro 17, in particular, is big, beefy, with a wicked arsenal of components—including a Core i7 10875H processor and an Nvidia GeForce RTX 2080 Super Max-Q too.

Its party piece is the screen compliments, however. It's up to you what you pick—you can either have the 4K touch 120Hz display shown here (which is genuinely beautiful to behold), or swap that out for the incredible color depth of one of only a few OLED 4K displays instead. Whether it's work or play, this premium device is beautiful to behold, and it won't fail you in game, or in the office.

● ***$3,800*** ● ***www.razer.com***
*Reviewed: Vol. 25, No. 10, PG 68*

SYSTEM

VERDICT 9 KICK ASS!

## Corsair One A100

Corsair's One series of systems is nothing if not impressive. Since first being introduced into the market the vast army of these things have swept up awards left and right, and we here at *Maximum PC* love them. This year's favorite is none other than the A100. This exceedingly expensive super tower features the 16-core AMD Ryzen 9 3950X, Nvidia GeForce RTX 2080 Ti, 32GB of DDR4 at 3,200 MHz, and 3TB of storage (a combination of PCIe SSD and HDD), all of which is cooled by a single 140mm fan and twin AIOs (one for the GPU and another for the CPU).

It's just a monster, and perhaps one of the most intuitively designed systems out there. Expensive? Absolutely. But 100-percent incredible, and for that it wins our award for system of the year. Expect new, updated variants with Ryzen 5000 processors and Nvidia GPUs to launch sometime in Q1/2.

● ***$4,000*** ● ***www.corsair.com***
*Reviewed: Vol. 25, No. 10, PG 66*

CORSAIR
ONE

HEADSET

VERDICT
9
K!CK ASS!

## Razer Kraken Ultimate

It takes a lot to impress us when it comes to a decent pair of headphones. They're one of the most subjective products in the world, not least because it's your ears that need to enjoy them, and everyone's ears are different. Nonetheless, Razer's Kraken Ultimate ticks nearly every box on our long list of criteria, providing epic clarity, a booming low-end, and a clever design.

These headphones are bold, brash, and definitely aimed at the gamers, and come with enough accessories to keep you suitably entertained and equipped for some time. They're not the cheapest cans out there, at $180, but for the price you can easily compare the Razer Kraken Ultimate to some headphones at almost twice that price and still not be able to tell the difference—they're that impressive.

● ***$180*** ● ***www.razer.com***
*Reviewed: Vol. 25, No. 3, Page 89*

MOUSE

VERDICT
9
K!CK ASS!

## Glorious Model O Minus

In the world of competitive gaming, these last 12 months have seen some epic developments take place, especially in the world of mice. The theory goes like this: The lighter the mouse, the quicker the mouse, and the faster the response time. And nowhere has this ethos been better represented than with the Glorious Model O Minus. It's seriously light, coming in at just two ounces. Most gaming mice (already fairly light) float in at around twice that figure.

Couple that with its brilliant build quality and epic Pixart PMW-3360 optical sensor, and the Model O Minus is a true king in the world of esports.

It comes in at just under the $50 mark, and makes for an epic gift for that younger *Fortnite* gamer in your life. Who knows, perhaps they'll go pro, and buy you a house one day!

● ***$50*** ● ***www.pcgamingrace.com***
*Reviewed: Vol. 25, No. 4, PG 87*

KEYBOARD

## SteelSeries Apex Pro

VERDICT
9
KICK ASS!

To give you an idea of why the SteelSeries Apex Pro is our favorite keyboard of 2020, we're going to tell you two things. Firstly, our editor currently uses one as his daily driver, and secondly, our resident modder and peripheral reviewer Dave does too. Dave liked it so much he removed all the switches and soldered in his preferred ones. If that doesn't speak volumes we don't know what does.

Ultimately the Apex Pro features a super clean aesthetic, fantastic lighting, an awesome software suite in the SteelSeries Engine, a fairly non-intrusive display, and with this particular edition, custom magnetic linear switches with adjustable actuation points. If that doesn't take your fancy, there's also TKL variants, and MX Red, Brown, and Blue versions too. Neat huh?

● ***$200*** ● ***www.steelseries.com***
*Reviewed: Vol. 25, No. 6, PG 76*

CASE

## NZXT H1

VERDICT
9
KICK ASS!

There's no other way to say it, the NZXT H1 is seriously impressive. At $350 it's not cheap, but it comes with its own cooling solution and power supply installed as standard, and looks absolutely stellar. It's not the easiest thing to build in, and there's no HDD support, but for anyone looking to build their own "Corsair-One-like" PC then the H1 is a fantastic case for it.

There is currently an issue with the PCIe riser cable potentially shorting out on the case itself, but NZXT has been quick to remedy the situation, and has offered repair kits to any and all who own one of these incredible pieces of engineering, which in our eyes speaks volumes.

● ***$350*** ● ***www.nzxt.com***
*Reviewed: Vol. 25, No. 6, PG 77* ⏻

# THE GRAPHICAL UNION ADDRESS: NOW WITH MORE RAY TRACING

The ray-tracing party is kicking into full swing, with AMD arriving fashionably late. *Jarred Walton* takes us on the tour

© CD PROJEKT

**OVER TWO YEARS AGO,** Nvidia surprised nearly everyone by announcing that its next-gen Turing architecture would feature the holy grail of computer graphics: Ray tracing (RT). It's a technique that's been around for decades, and the movie industry makes extensive use of it these days—or at least it did, back when movies were still being made, and we could go out to watch them. The thought of getting hyper-realistic visuals in games that could rival the latest blockbusters sounded too good to be true, and it was. Today, we have Nvidia's second generation of RT hardware in the Ampere architecture, and AMD has joined the fray with its RDNA2 GPUs. It's time for a State of the Union address on the subject of ray tracing in games.

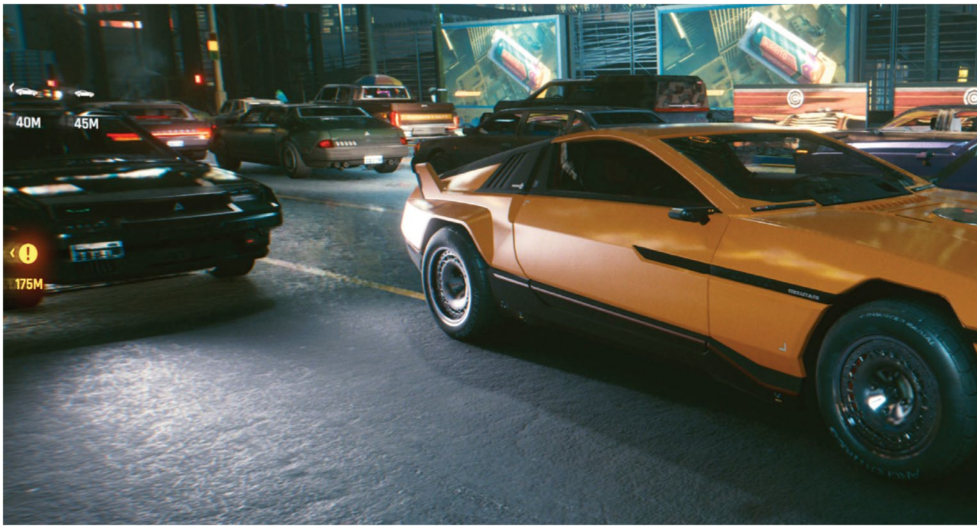
## A BRIEF OVERVIEW OF RT EFFECTS

We're not going to dig deep into the details of how RT works—that's familiar territory by now. The short summary is that it involves calculating the projection of lines (rays) into the geometry of a scene to figure out what polygon the ray intersects, and then depending on the material properties of that polygon, additional rays can be cast. Ultimately, the results of all those individual rays are then combined to determine the final color value for a pixel.

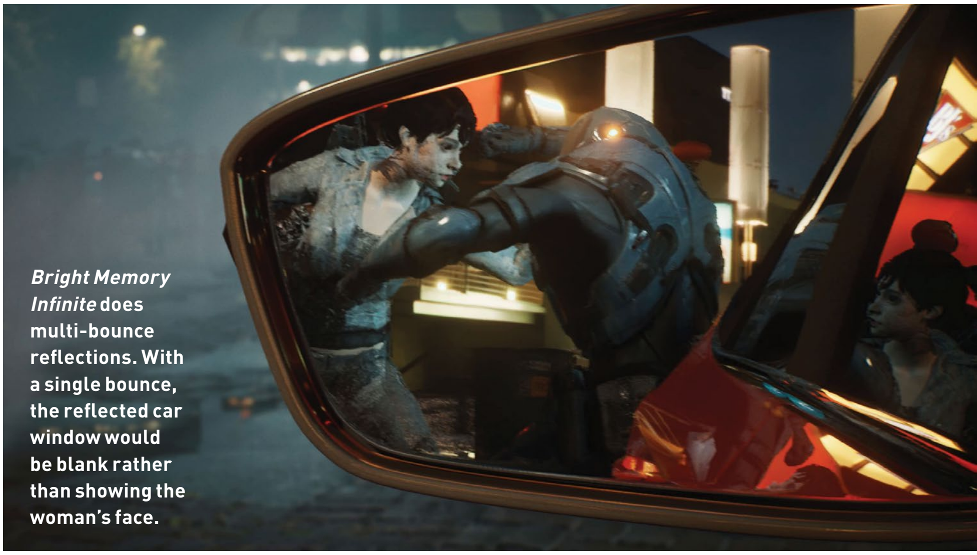
While it might seem like a single ray per pixel would suffice, it doesn't really get the job done. Each bounce counts as a new ray, and there are different types of material and ray calculations that need to be done. The main takeaway is that fully ray-traced scenes in movies can use hundreds or even thousands of rays per pixel, and take hours of rendering time per frame. That's many orders of magnitude slower than what we want from PC games. Even a relatively "fast" rendering time of 10 minutes per frame in a movie is still about 2 million times slower than a PC game running at 60 frames per second.

The trick for real-time ray tracing is to find a compromise between quality and performance. GPUs containing RT hardware aren't going to give us a million-fold speed-up, but by combining the results of rasterization where it looks good enough with RT, it's possible to get hybrid rendering up to real-time levels of performance. That's the idea, at least.

In general, rasterization is really good at handling textures and geometry, and shader calculations and post processing effects can further improve the resulting output. Ray tracing doesn't need to reinvent the wheel, then, but instead just focus on improving the areas where rasterization comes up short. Here's a quick overview of the major RT effects being pursued right now in games.



**The use of RT for global lighting, shadows, and reflections enhances the road rage of the Night City denizens when someone parks their car in the middle of the road.**



***Bright Memory Infinite* does multi-bounce reflections. With a single bounce, the reflected car window would be blank rather than showing the woman's face.**

## RAY-TRACED EFFECTS

**•Reflections:** This is a great example of where RT has real advantages over traditional rendering modes, as the rays can bounce into areas of the scene that aren't directly visible. It's easy to set up an environment where the presence or lack of proper reflections makes a huge difference in how things look—2019's *Control* being a great example with its mirrored office environments. You can even take things a step further with multiple bounce reflections, where a ray that hits a reflective surface and bounces into another reflective surface keeps propagating, which is required to render a hall of mirrors effect. Of course, more reflections and more rays mean slower performance, but the *Bright Memory Infinite* demo has some great examples of how more complex RT modes can improve the overall visual fidelity.

Right now, the list of games using ray tracing for reflections continues to grow, with at least 10 games released and more on the way. *Control*, *Cyberpunk 2077*, and *Watch Dogs Legion* are some of the best examples. The problem is that even though reflections can make a big visual difference, there are still scenes where they hardly matter, yet the performance hit remains. Plus, even though screen space reflections miss some things (stuff that's not currently visible on the screen can't be reflected), SSR often does a reasonable job at faking it.

Limited RT reflections can also break the illusion the game is trying to create. Case in point: *Cyberpunk 2077* apparently doesn't have a model for the player character V present in the game world. That or V is for "vampire" and so V doesn't cast a reflection. Either way, it feels very weird to walk up to a car window and not see your player. Oddly, you can "turn on" mirrors in bathrooms to see your reflection, and V is present in the game's photo mode, but after playing *Control* and *Watch Dogs Legion*, *Cyberpunk 2077*'s missing reflections just feel wrong—and may end up getting patched by the time you read this.

**•Shadows:** Proper shadows require looking at how much light reaches each surface, which can be incredibly computationally expensive if there are lots of lights in a scene—not to mention surfaces that can reflect lights. Most games tend to implement RT shadows for only a few light sources, focusing on those

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that are within a certain distance from the objects, plus a single global light source.

Our impression is that RT shadows are at the other end of the spectrum from reflections, in that they've been decidedly disappointing so far. It's not that RT shadows don't make a difference in visuals, but do they make a big enough difference? That's the rub. In practice, shadow-mapping techniques tend to look good, and more advanced solutions can mimic soft shadows while still performing better than RT shadows. *Shadow of the Tomb Raider* and the two latest *Call of Duty* games are good examples of how little RT shadows often matter, and they still generally omit proper shadows for things like procedurally generated foliage.

•**Global Illumination / Lighting:** This one gets a bit nebulous—isn't lighting sort of the same as shadows? But here the focus is on figuring out how much indirect lighting reaches a surface, as well as the color of the lighting. For a pure RT implementation, it's possible to basically lump a lot of these effects together in a single unified engine, but then we're back to millions of times more complexity than is perhaps necessary for a game.

*Metro Exodus* only used RT for GI, and it could certainly make a difference inside some buildings. One example that was shown when the game launched was how proper GI leads to darker shadows in some areas of a room, but lighter areas in others. A building with a single window to the outside, for instance, doesn't just have a bright rectangle where light enters the room. Instead, you get a lit-up area that in turn makes the rest of the room at least partially visible. Without RT, most games define a general minimum lighting level so that non-lit areas aren't just black, but it's not realistic.

The problem is that sometimes realism isn't as fun. There's a scene in a helicopter in *Cyberpunk 2077*, for example, that takes place at night. With RT enabled, all you can really make out is the dark silhouette of a person aiming a mounted minigun. Turn off RT and suddenly there are multiple people and lots of equipment inside the helicopter. It's not necessarily

## PURE RAY-TRACING PERFORMANCE?

**How far are we away from doing pure ray tracing in a game? Theoretically, it could be done right now, but how would it perform? The best estimate we have of how a pure RT rendering solution would perform comes from 3DMark, with its DirectX Ray Tracing Feature Test. We ran the test on the latest AMD and Nvidia RT-capable GPUs, and it uses a relatively ambitious 2560x1440 resolution. Full ray tracing at 1440p? We could be in for a bumpy ride!**

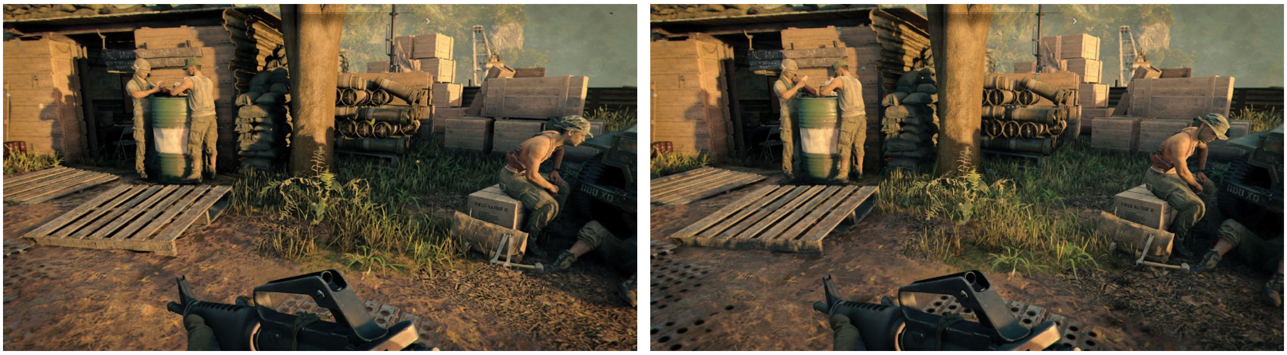
### 3DMARK DXR FEATURE TEST (AVG. FPS)

| RTX 3090 | RTX 3080 | RTX 3070 | RTX 3060 Ti | RX 6900 XT | RX 6800 XT | RX 6800 |
|---|---|---|---|---|---|---|
| 57.4 | 48.4 | 32.8 | 27.4 | 29.6 | 27 | 22 |

**OK, honestly that doesn't even look that bad. The 3090 is already hitting nearly 60fps! Except, you have to see the test in action to understand what's happening, and how it differs from a real game.**

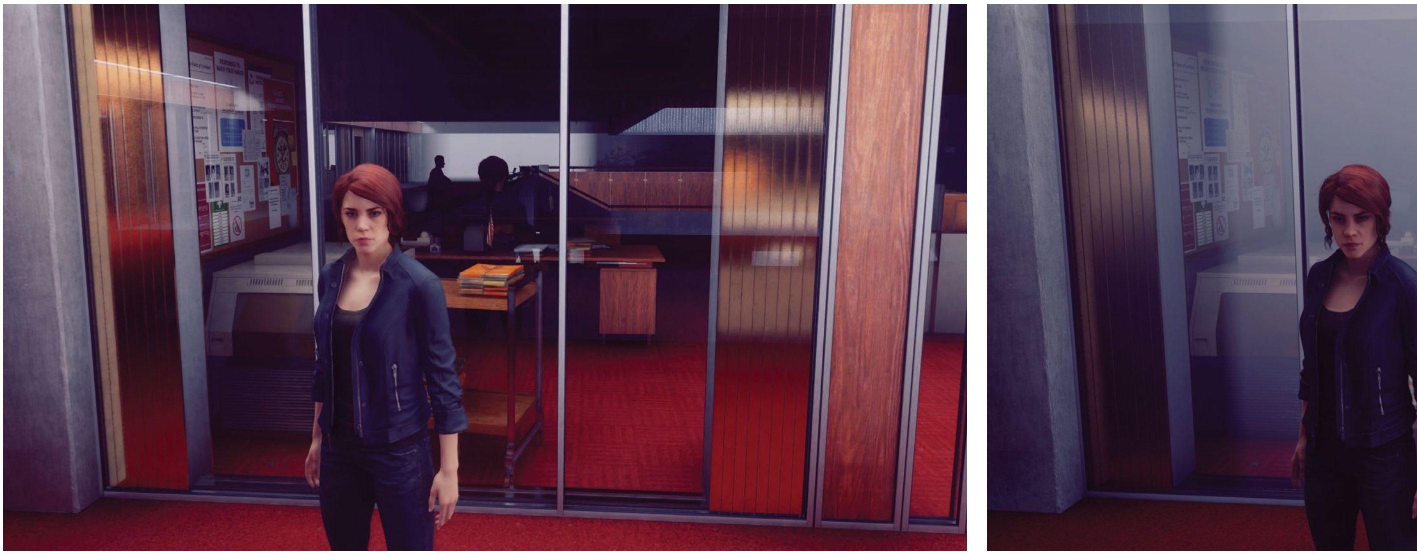
**The whole test uses a static scene, and the camera moves around, adjusting focal length at times. Once the camera stops moving, the randomized rays being cast converge on an ideal ray-traced rendering of the scene, and things look pretty good. But when the camera's moving, each pixel only gets 12 rays cast per frame, which results in pixel noise—especially apparent on the slower GPUs.**

**So, maybe this isn't a true representation of a fully RT game engine. However, it does give us an interesting comparison of the latest GPUs, and the picture it paints doesn't look too good for AMD. AMD's fastest GPU, the 6900 XT, barely beats Nvidia's 3060 Ti, currently the slowest Ampere GPU. AMD also falls behind Nvidia's previous-generation RTX 2080 Ti. What's particularly concerning is that even the RX 6800 is faster than the new consoles, which means the best the consoles can hope for is about one-third of the pure RT potential of the RTX 3090.**



***Call of Duty* focuses its use of RT on shadows and ambient occlusion. These improve the overall feel, but rasterization looks good anyway.**

© ACTIVISION BLIZZARD



***Control*** **is filled with reflective surfaces, including puddles, mirrors, and glass, combined with RT shadows and diffuse lighting.**

that the RT implementation is wrong, but in the real world there would likely be other light sources that simply aren't included in the game.

**•Ambient Occlusion, Refractions, and Caustics (oh my!):** These last three effects aren't quite as eye-catching as the above, so we're putting them all into one pot. Refractions have to do with the way light bends as it passes through a transparent object, such as glass or water. Frankly, a rough approximation of the distortion done via shaders is probably good enough for most games. Caustics is related to refractions, and has to do with the bright focus areas of light that you can get, such as with a magnifying glass or even a glass of wine. Cool? Perhaps, but also not critical for most games. Then finally there's AO, which focuses on the way shadows tend to be darker in corners where polygons intersect.

The story is pretty much the same for these as for the earlier RT effects: Some things clearly look better, while other aspects hardly seem to change, and the performance hit remains. Can we see the difference between the varying forms of ambient occlusion—SSAO, HBAO+, or RTAO? Yes. Does RTAO look best? Yes. Would we actually notice the change in AO if we weren't specifically looking for it? Perhaps in a more cerebral game, but in a fast-paced shooter, probably not.

## BUILDING FOR THE FUTURE

What we're getting at is that RT still feels very much in its infancy, as far as games are concerned, and game developers aren't free to focus on the RT implementation as long as a significant percentage of the PC ecosystem still consists of old non-RT GPUs. And it does, if we're going by the Steam Hardware Survey, which shows only 12 percent of all PCs using an Nvidia RTX graphics card. (It also shows 7 percent of PCs surveyed still using Intel integrated graphics.)

This isn't something new or unusual. We've been through this same sort of progression multiple times. There was the shift from 2D to 3D accelerators in the 90s, the "first GPUs" that added hardware transform and lighting support in the late 90s, and multiple generations of hardware-programmable shaders. Each time, it took years before the old hardware was truly abandoned by newer games. The past two years of consumer RT hardware have just been the latest case of hardware preceding the software.

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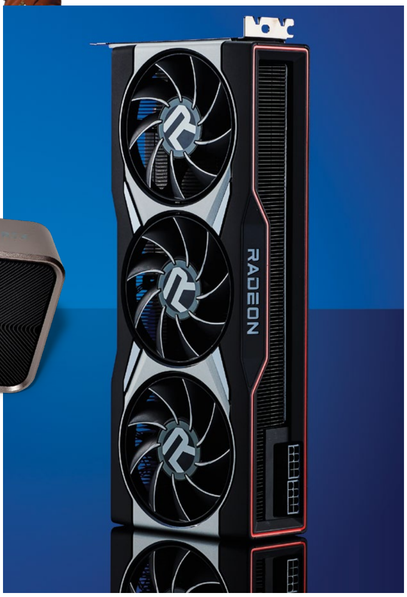
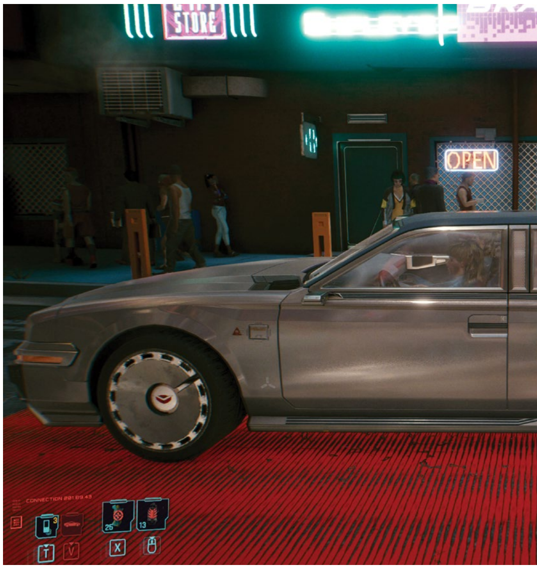


***Above:*** **Second-gen ray tracing has led to a 70 percent performance increase compared to the 2000 series.**

***Right:*** **AMD's Radeon RX 6000 series is the first AMD GPU to support ray tracing, though it's still early days for performance.**



**With DLSS enabled, and ray tracing disabled, even the**

© CD PROJEKT

The good news is that things are starting to change. Nvidia is no longer the only ray-tracing solution in town. Now that AMD also has hardware RT support for both PC GPUs and the latest consoles, we could potentially see an acceleration in the use of RT. When will it become a required feature? Judging by the way things are progressing, we're at least five years away from that happening for the biggest releases, and probably more like 10 years away. Individual games might decide to require RT hardware, but it's going to take a long time before major studios are likely to go all-in on ray tracing.

Part of that is simply a matter of economics. Major game launches have already reached the level of Hollywood movies, with costs in the tens of millions of dollars (or more), and that's with relatively tame visuals. If we want RT games to look anything like RT movies, it will require even more artistic talent to make RT shine. To recover the costs of creating a game, publishers need to be able to sell as many copies as possible, and that sits in direct opposition to the idea of making a game that requires RT hardware support.

In other words, we have the classic chicken and egg scenario. Game developers want more gamers to have RT-capable hardware before they pour resources into creating RT games. Gamers, on the other hand, want to see some real advantages for RT hardware before they're willing to fork over the money for a graphics card upgrade. That brings us to the AMD vs. Nvidia (and maybe Intel) discussion.

## MEET THE HARDWARE CONTENDERS

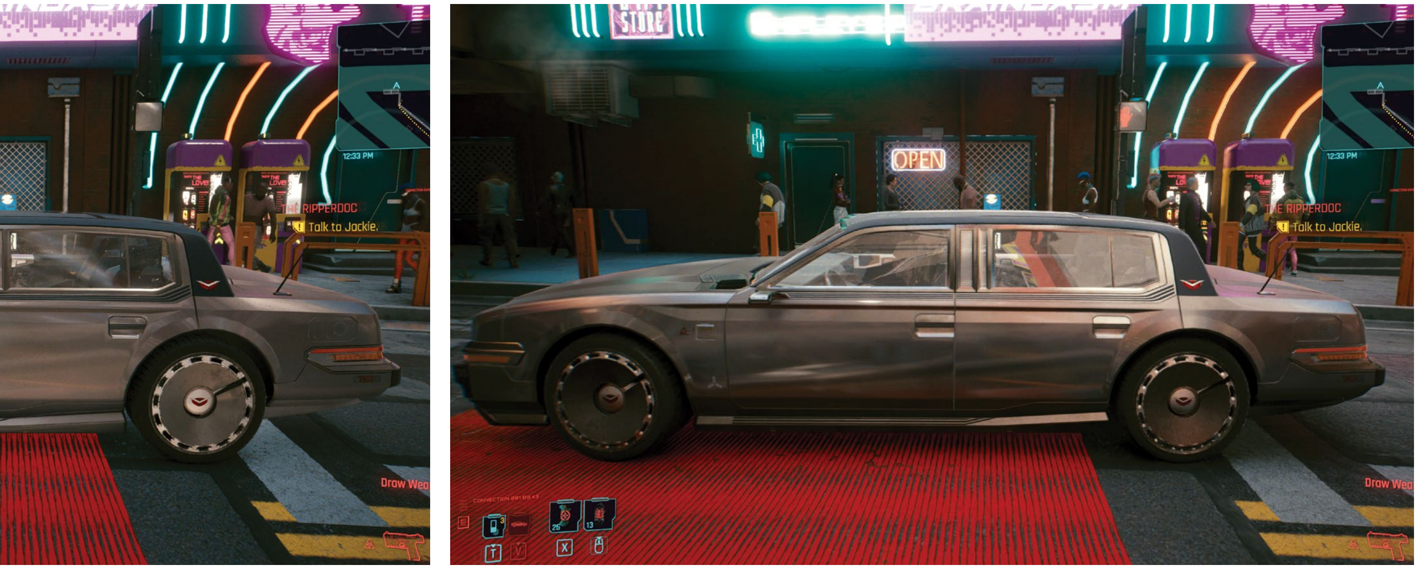
Let's move on from what ray tracing can do for games and look at the hardware implementations. Nvidia has first-gen RTX 20-series GPUs that have defined the baseline for RT performance. The new Ampere architecture ushers in the second round of Nvidia RT hardware, promising up to double the performance for RT calculations. AMD, meanwhile, has just released its first-gen RT hardware, the RX 6000-series RDNA2 GPUs. How do the various GPUs compare in terms of RT capabilities? Well it depends.

Nvidia hasn't disclosed a lot of the low-level details about how Ampere and Turing RT cores differ from each other. We know that Ampere has an additional ray/triangle intersection functional unit, and Ampere's RT cores also have the ability to take a time component (useful for things like RT motion blur). While Ampere is theoretically up to twice as fast as Turing per RT core, in practice Nvidia says that it's about 70 percent faster. Unfortunately, that's only scratching the surface of what the RT cores do and how they work.

For example, we know that Nvidia's RT cores can perform ray/bounding box intersections in addition to ray/triangle intersections. This is all part of the BVH (Bounding Volume Hierarchy) implementation used for RT in both DirectX Raytracing (DXR) and VulkanRT. In short, BVH is a structure that helps accelerate the process of determining which, if any, triangle a ray intersects. Rather than checking the ray against every triangle, it starts with comparing the ray against bounding boxes that get progressively smaller, until the algorithm reaches a point where checking a ray against individual triangles makes sense.

What we don't know exactly is how fast Nvidia's GPUs are at ray/box vs. ray/triangle intersections. There are some situations where Ampere can do twice as many RT calculations per cycle, and others where one of the functional units may go unused. For AMD's part, the RDNA2 GPUs have Ray Accelerators that can do either four ray/box intersection calculations per cycle, or one ray/triangle intersection. It's also unclear if different types of RT calculations—for example, for reflections vs. shadows vs. global illumination—take different amounts of time per ray, or if they simply require more rays in general.

With hardware in hand, however, it's possible to run tests to get a reasonable estimate of the performance—see Pure Ray Tracing Performance on page 29. That's one specific test of RT performance,



**3060 Ti can play *Cyberpunk 2077* at 4K 60 fps, albeit with some loss to fidelity.**

## DIRECTX RAY TRACING PERFORMANCE (AVERAGE FPS)

| | RTX 3090 | RTX 3080 | RTX 3070 | RTX 3060 Ti | RX 6900 XT | RX 6800 XT | RX 6800 |
|---|---|---|---|---|---|---|---|
| 10-Game Average | 68.1 | 60.2 | 45.4 | 39.4 | 48.1 | 44.5 | 37.7 |
| 3DMark Port Royal | 60.8 | 53 | 37.4 | 32.3 | 45 | 42.8 | 35.4 |
| Boundary | 48.8 | 42.8 | 30.7 | 26.7 | 28.4 | 26.3 | 22.1 |
| Call of Duty: Black Ops Cold War | 87.8 | 79.7 | 63.7 | 54.4 | 51.4 | 48.6 | 42 |
| Control | 71.6 | 62.9 | 44.9 | 39.8 | 40.2 | 38.2 | 33.3 |
| Crysis Remastered | 67 | 62.5 | 52.7 | 43.9 | 55.5 | 46.9 | 40.8 |
| Dirt 5 | 88.6 | 77.7 | 59.2 | 51.7 | 83.7 | 83.6 | 72.7 |
| Fortnite | 37.8 | 32.5 | 23.4 | 20.3 | 28.2 | 23.4 | 18.9 |
| Metro Exodus | 81.3 | 71.7 | 54.4 | 47.1 | 56.8 | 55.9 | 47.1 |
| Shadow of the Tomb Raider | 104 | 92.4 | 70.4 | 63.1 | 85 | 79.8 | 68 |
| Watch Dogs Legion | 60.8 | 52.7 | 40.3 | 35.2 | 39.3 | 35.3 | 29.7 |

All tests performed at 1440p ultra settings, with ray tracing enabled. Test PC consists of a Core i9-9900K, MSI MPG Z390 Ace motherboard, 2x16GB DDR4-3600 memory, and a 2TB M.2 SSD.

and it may not be applicable to all RT implementations, but it does provide interesting data points. Which brings us to the final topic: Actual RT performance in currently shipping games.

### RT HARDWARE PERFORMANCE

We selected 10 graphics tests and games that use the DirectX Raytracing API and run on both AMD and Nvidia GPUs. That last point is important, because there are currently two games that use DXR and only work on AMD GPUs (*Godfall* and *The Riftbreaker*), and at least a few tests and games (*Bright Memory Infinite*, *Cyberpunk 2077*, and *Wolfenstein Youngblood*) that only work on Nvidia GPUs. Not surprisingly, each of the games is promoted by the respective GPU company, so the upcoming RT gaming wars could get messy (see table above).

Right now, it looks like Nvidia is crushing AMD in RT performance. Overall, the RTX 3070 comes in just ahead of the 6800 XT, and the 3080 is 25 percent faster than AMD's RX 6900 XT. As for the 3090, it's in a class (and price) of its own.

But then we look at *Dirt 5* and have to wonder how much vendor-specific optimizations play a role. There, the 6800 XT beats the 3080 by 8 percent. Yes, this is an AMD-promoted game, and the DXR is still in beta. Maybe Nvidia will close the gap, and to be fair the RT effects in *Dirt 5* aren't particularly impressive. As for the other games, they came out before AMD's RX 6000 series launched, which means they were optimized for Nvidia by default.

The thing to keep in mind is that AMD RDNA2 GPUs are in both the PlayStation 5 and Xbox Series S/X, which means that every console game that implements RT will be targeting AMD by default. Only time will tell how that muddies the waters.

### RESOLUTION UPSCALING: GETTING MORE FROM LESS

There's still one more important aspect of ray tracing that we haven't discussed: DLSS (Deep Learning Super Sampling). RT is computationally intensive, so any way to reduce the number of rays cast is extremely helpful. RT solutions already use denoising to help improve performance, but the goal of DLSS is to reduce the number of pixels rendered from the start.

At its core, the idea of DLSS is pretty easy to grasp. Use machine learning to train a deep-learning network on how to upscale and anti-alias games. The trick is that while the training process can be incredibly time-consuming, the inference aspect—using the trained network and running it against frames in a game—is far less demanding. Across the five DLSS 2.0 games we tested, DLSS Quality mode improved performance on the RTX 3060 Ti by 65 percent at 1440p.

For games that support Nvidia's proprietary tech, Nvidia GPUs enjoy a commanding lead over AMD. Even the

***Crysis* was one of the first games to truly push the boundaries of what we could do with revolutionary new shader tech. Ray tracing is much the same.**

© CRYTEK

RTX 3060 Ti outperforms the RX 6800 XT by 50 percent on average in games that use the latest DLSS 2.0 implementation—and that's using the DLSS Quality mode; higher performance DLSS modes are also available.

How does it look? If you take screenshots of native rendering and DLSS rendering and compare them, sometimes DLSS looks better than native with TAA (Temporal Anti-Aliasing); other times it looks perhaps a bit worse. In motion, though, you'd be hard-pressed to tell the difference—except for the fact that DLSS runs at far more palatable frame rates.

AMD is working on an alternative to DLSS—FidelityFX Super Resolution. The thing is, DLSS 2.0 is here, support is integrated into Unreal Engine, and quite a few game developers and publishers have also jumped on the DLSS train. And why wouldn't they? RT is so demanding that even the mightiest of GPUs can struggle at higher settings, especially at higher resolutions. With all the RT options maxed out, not even the RTX 3090 can maintain 60fps in *Fortnite*—though it can with DLSS enabled.

Perhaps more important than ray tracing right now, DLSS has very tangible benefits. Games such as *Cyberpunk 2077* can even use DLSS without enabling RT, which makes 4K viable on cards like the RTX 3060 Ti. A $400 GPU, running the most anticipated game of 2020 at maxed out settings (minus RT) and 4K at 60fps? Yeah, we didn't see that coming at the start of the year. The 3060 Ti can also do maxed out RT with DLSS at 1080p and 60fps if you prefer.

**Intel's expected to launch its Xe Desktop GPU in 2021, and it needs to compete.**

## WHAT ABOUT INTEL?

**It's easy to start thinking about graphics and ray-tracing GPUs as a two-pony show. There's AMD on the one side and Nvidia on the other. But Intel doesn't intend to be left out, or at least that's what it claims.**

**For the past few years, Intel has been working its way toward releasing dedicated graphics cards. Headed by Raja Koduri, formerly of AMD's GPU division, 2021 is the year when we'll finally see the fruits of Intel's labors. There will be multiple products, ranging from low-power integrated graphics solutions to high-end gaming cards, and all the way up to data center-focused parts for supercomputers. Xe LP already exists in the latest 11th-Gen Core mobile CPUs (AKA Tiger Lake), but the dedicated cards will be a different story.**

**How different? That's the $20,000 question. Xe HPG stands for High Performance Graphics, and Intel should have a good idea of what it's up against. It needs to go toe to toe with AMD and Nvidia if it's going to succeed. That means more than just hardware, as drivers are important in modern graphics cards.**

**So far, Intel's Xe LP Graphics have been impressive for 15-25W devices, but they're nowhere near the level of performance offered by dedicated GPUs. Put more bluntly, GTX 1050 is faster, and that's a three-year-old $110 GPU. What we don't know yet is how Xe will scale up to 250-300W parts with far more computational power. We do know that Intel is planning on supporting ray tracing, both DXR and VulkanRT, with Xe HPG. Hopefully it will be fast and competitive rather than weak and late to the party.**

### RAY-TRACED MOUNTAINS TO CLIMB

Two years on, and it's interesting to see what has changed and what hasn't. Nvidia is faster at RT, and enabling RT in most games is still a great way to tank performance for a modest improvement in visuals. But in the right situations, RT can make a big difference. There's no way to get high-quality visuals suitable for film without ray tracing or path tracing, and while games continue to improve, we're a long way off from playing anything that has visuals worthy of a summer Hollywood blockbuster.

One thing that has changed since the first RTX cards launched is the number of games with support for ray tracing. Big publishers may have been first out of the gate, but those first forays into real-time RT feel pretty lackluster compared to some of the latest games. At present, there are currently around two dozen games that use RT in some form, with many more currently in the works.

It's funny how we can get used to games looking a certain way and be happy with it, and then along comes something new and our expectations change. *Control* paved the way with a new level of visual fidelity, and *Cyberpunk 2077* now joins it, with most other games still trying to catch up. While you can certainly play either game without ray tracing, once you've spent some time running around the hallways of the Federal Bureau of Control or Night City in all their RT glory, you miss the improved reflections, lighting, and shadows once they're gone.

We remember the days of the first programmable shader GPUs, with games like *Crysis* causing hardware to physically cry out in pain at times. It took many years before that level of graphics became relatively commonplace, and ray tracing will follow the same path. We're still nowhere near the point where RT hardware has fully penetrated the market. Part of that is thanks to the rise of laptops. 12 percent of all PCs on Steam might have RT-capable GPUs, but if we're looking purely at laptops, that number will certainly be lower. Consoles getting RT hardware was probably necessary before we'd get to see the tech proliferate.

With the latest GPUs, we now have cards that are significantly faster than two years ago, and future generations will continue the upward climb. In that sense, right now we're really just trudging through the mist-shrouded foothills of ray tracing, looking up to the summit in the distance. It's going to take time to get there, but in another two or three generations of graphics hardware we'll think back fondly on our hike through the valley of rasterization and conclude that, yes, the ray-traced panorama before us was worth the effort.⏻

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GRAPHIC INDEX
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ANUAL
April 28, 1983
Bob Kirschenbaum
Pacific Press Services
Tokyo C.P.O. 2051
Tokyo, Japan
Dear Bob,
All is well here. We really are go
photos to you very soon. We have no
recently, but we have two shipments
Catherine to caption and send to you.
long.
I want to let you know that my parents
Arlene Hayens, will be in Tokyo next w
will be on a business trip so have no
free time they will have. But I have g
your name and telephone number in case

# RETRO COMPUTING AHEAD OF ITS TIME

## *JOHN KNIGHT* LOOKS AT WHERE WE'VE COME FROM, AND WHERE WE'RE GOING

© GETTY IMAGES

**IN THE 2020S,** Our CPU speeds are measured in gigahertz. Our RAM size is measured in gigabytes. Our machines are thousands of times faster than when home computing started. It's easy to look at how far computing has progressed and be smug. But is it possible that we think we've progressed further than we really have?

Try watching old episodes of *The Computer Chronicles* or *The Computer Programme* (BBC, UK) and it can be very surprising to see what they could do with technology of the past—computers that were thousands of times slower than what we have now, or just entirely different. From analog and mechanical computing, to early inter-planetary digital photography; from early multimedia, to an internet before the internet—history is full of technological sophistication, largely driven by methodologies that have fallen out of favor.

Join us as we look back through computing history at accomplishments that seem almost impossible for the tech of the day. We'll look at computing before the modern digital age, 20th-century technology ahead of its time, and a special look at the most tech-mad decade of all: The 80s.

# ANCIENT AND NOT-SO-ANCIENT COMPUTING FEATS

Computing's distant past is full of incredible engineering feats, with computing accomplishments that boggle the 21st-century mind. Here's a small selection of computing feats that happened earlier than anyone would believe.

## ISMAIL AL-JAZARI: ANCIENT ROBOTICS

Considered by many as the father of robotics, Ismail al-Jazari (1136-1206) designed the first humanoid "automatons," and could also be considered as a sort of ancient open-source advocate.

In 1206 al-Jazari compiled his works into a tome dubbed *The Book of Knowledge of Ingenious Mechanical Devices*. Al-Jazari included meticulous diagrams on how his machines were constructed, and his book is often considered a DIY guide. While other inventors used obscure language, limiting their works to elite circles, al-Jazari used plain language that was accessible to a wider audience in the hope that others would continue his work.

Al-Jazari's inventions were centuries ahead of European science and an inspiration to Leonardo da Vinci. Many of his creations still exist in some form today, and his inventions of camshafts and general methods for converting between horizontal and rotational movement formed the basis of the industrial revolution.

Of particular interest to scientific historians are his musical robot band and the Castle Clock. His robot band was a boat with four water-powered automatons, built to entertain guests at royal parties. Of particular note is the drummer, which was a programmable drum machine driven by pegs on cams. Rhythms could be pre-programmed by moving the positions of the pegs, which would in turn strike levers that operated the percussion. Apart from being a programmable drum machine—presumably the world's first—it's also considered to be the first programmable robot.

As for the Castle Clock, this was a highly intricate device that not only kept time, but would also keep track of zodiac placements, plus solar and lunar orbits. Other features included different mannequins that would appear at hourly intervals, as well as mechanized falcons that would drop balls into vases.

Of particular note to techno-historians is its ability to reprogram the length of days, in order to account for seasonal changes. This makes it the earliest known programmable analog computer.

## LORD KELVIN: ANALOG COMPUTING'S HEYDAY

In 1872 British mathematical physicist Sir William Thomson (1824-1907, later known as Lord Kelvin—yes, that Kelvin!) developed a tide machine, something that would go on to be foundational to the field of analog computing in the first half of the 20th century.

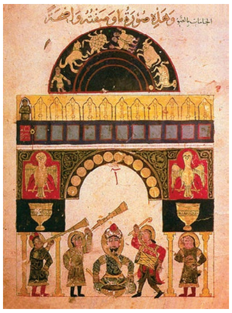
Tide prediction had existed for a couple of centuries, starting with Isaac Newton's theories of the Sun and Moon's effects on Earth's tides, and advanced by Pierre-Simon Laplace in the 1770s, and George Darwin in the 1860s.

However, the formulae and methods were phenomenally complex undertakings, calculated manually by humans, making tidal prediction a complicated and highly error-prone undertaking. This state of affairs would not do for Sir Thomson, who was known as a master of measurement and a prolific inventor.

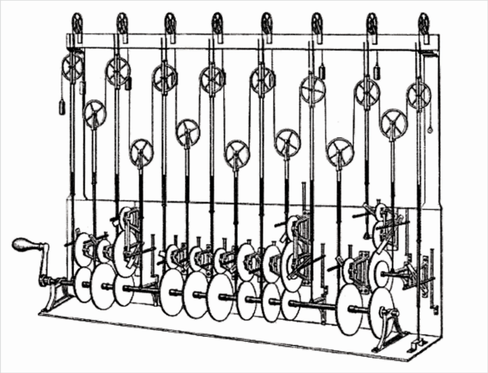
Using an elaborate system of pulleys and wires, Thomson's machine was able to automatically predict tide levels for a particular location at a set time. Larger, more advanced machines were made in the years to come, and variants were made by the US and Germany, all of which was strategically vital during World War I.

Thomson's work continued in the field, where he built a harmonic analyzer in 1876, which used an assembly of discs to sum trigonometric series. Thomson noted that a similar device would be able to solve differential equations.

One of around 30 Thomson tide-prediction machines is on display and in full working order



**Al Jazari's Castle Clock was a thing of beauty.**



**Kelvin's tide machine helped found the very basis of analog computing.**

**The Normandy landings wouldn't have been possible without the help of Kelvin's tide machine.**

© WIKIPEDIA, GETTY IMAGES

at the National Oceanography Centre, Liverpool, UK. Built in 1929, the machine helped to predict the tides for the Allied Normandy Landings in 1944.

## CHARLES BABBAGE: MECHANICAL COMPUTING & STEAMPUNK DIGITAL

So far we've looked at analog computers, which are extremely different to today's digital computers. For the origins of digital computing, history books usually start with Charles Babbage (1791-1871).

Starting with the Difference Engine in 1832, Babbage created a crank-driven mechanical computer that displayed digits on rotating dials. If you're thinking, "So it's an old calculator, big deal," this was far beyond what your pocket Casio can do. This machine could solve complex equations, follow numeric sequences, and even extract the root of a quadratic equation. The Difference Engine is historically interesting from a programming perspective because it could be programmed to display a specified number when triggered by another number.

However, this was only a prototype, and the full engine needed to be built. Although Babbage managed to raise initial funding for the project, constantly changing design goals and a falling out with his engineers meant that the British government withdrew funding, and it was never completed. Babbage was cruelly mocked nationally.

The Difference Engine was a milestone in computing history regardless of its fate. However, it still wasn't really what we would call a digital computer. This was only a mechanical computer. For the genesis of digital computing we need to look at the Analytical Engine.

To be clear, the Analytical Engine was only designed, not constructed. But looking at Babbage's design is almost scary: It had punch card programming, 16.2 kilobytes of storage, something similar to a CPU called "The Mill", and even a programming language like Assembly.

In short, the Analytical Engine had the basic components of modern computing, with similar specifications to a mid-20th century mainframe, albeit quite a bit slower and also probably even more gigantic!

Given that the Analytical Engine was never built it would be easy to dismiss the project as a flight of fancy, but modern analysis reveals that the machine would have worked.

Enough design existed at least for Babbage's friend Ada Lovelace to write a theoretical algorithm for the machine, for which history generally credits Lovelace as the first programmer. And yes, the first programmer—in the digital sense of the term—was indeed female.

If only the UK had stuck by Babbage, and if only Babbage had the humility to listen to his paymasters' concerns, then Britain could have had a computing revolution a century early.

## EARLY DIGITAL TRANSMISSION FROM OUTER SPACE

Although it isn't common knowledge in the West, Soviet space programs in the 1970s managed to land probes on Venus, sending back digital photos from the surface of our nearest planetary neighbor.

Starting in the 1960s and ending in the 1980s, the Venera program (Russian for Venus) became Russia's focus after a series of Mars probes experienced high rates of failure. With Venus being closer to Earth than Mars, it was felt by the Soviets that that planet could be reached and explored more reliably.

Even though Venus is closer to Earth than Mars, the planet posed its own challenges to the Russians, requiring probes that could withstand extreme heat and atmospheric pressure long enough to send back surface data to Earth.

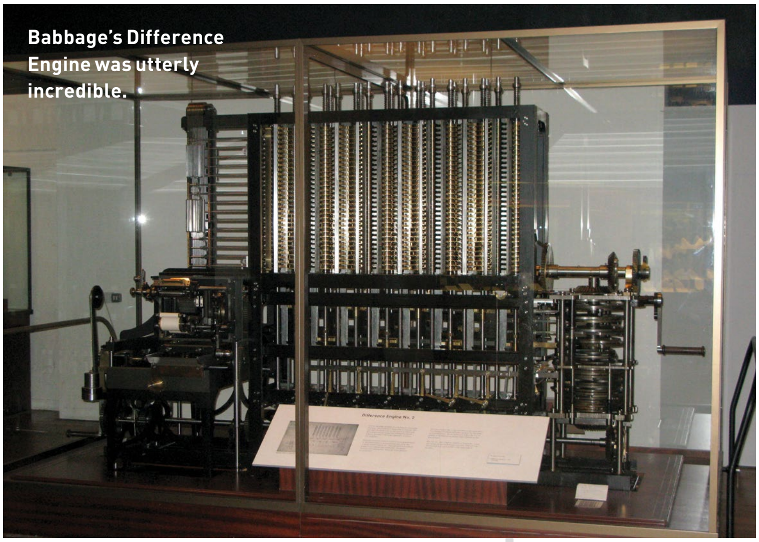
The Soviets sent 16 probes in all, gathering useful information, such as telemetry data, chemical compositions, and temperature readings, but it was with Venera 9 and 10 that they were finally able to take photos of the surface.

These spacecraft were significantly strengthened over earlier probes in order to survive the hellish temperatures (around 860° F) and crushing Venus atmosphere, 92 times the pressure of Earth. The probes were sent to opposite sides of the planet, transmitting data by radio waves for around 50 minutes before burning up in the Venusian heat.

The images were only black and white and low resolution by today's standards—only 512 wide x 115 high. But this was early digital photography nonetheless, and image reconstruction techniques in future years were able to bring impressively sharp images.

In 1982, the Soviets returned to Venus with Venera 13 and 14, sending back higher resolution images (1024 x 252) in color. They also sent back the first audio recordings of Venus, with the intention of measuring wind speeds.

All of this data managed to paint a fuller picture of a Venusian landscape: Endless deserts of black rock sprawled out under a yellow sky, while 223mph winds raced across in a carbon dioxide atmosphere, smothered in clouds of sulfuric acid. Brutal but fascinating.


Babbage's Difference Engine was utterly incredible.

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## ANALOG COMPUTING?

**Although analog computers were poised to be the future, by the 1960s the computing world had switched to a digital model.**

**Unlike their digital counterparts, analog computers use physical means to make calculations, such as pulleys, cogs, electricity, or hydraulics—read-outs are usually on dials or gauges. As such, one needs to allow for physical tolerances and a certain amount of error correction, meaning that analog computers can't be relied on to return the same precise values repeatedly.**

**But analog computing will never really disappear. If you've ever used a slide rule, this is a simple form of analog computing, and hybrid analog-digital systems are still used in areas like aircraft navigation.**

**A big advantage in analog computing is that it side-steps the digital world's need for computing power, as long as someone can design a system to suit.**

# BACK TO THE FUTURE: THE TECH-CRAZED 80S

The 80s: A time when computers and video games finally became household items, and people went gadget mad. We laugh at some of these now, but as you will see, some of the technology was way ahead of its time. We'll also throw in a little of the 90s too!

## GRAPHICS, VIDEO, AND SOUND: ATARI AND COMMODORE'S ADVANCED MULTIMEDIA

In 1985 computing experienced a sudden jump forward with two 16-bit machines: The Atari ST, and the Commodore Amiga. Bear in mind that the Commodore 64—the king of the 8-bits—had only been around for a couple of years before these next-generation machines arrived!

Based on the Motorola 68000 CPU, these new computers used a processor that until then was mostly used in expensive industry workstations and arcade machines. There was of course Apple's original Macintosh (1984), but this was very small, black and white, limited in its multimedia capabilities, and very expensive. In comparison, the Atari and the Amiga were reasonably priced and incredibly powerful for the money.

Where Commodore's strategy was to fit dedicated hardware for sophisticated graphics and audio, Atari opted for brute force by using a faster CPU and fitting twice the RAM as the Amiga, while substantially undercutting Commodore on price.

While the established 8-bit microcomputers and IBM-compatible PCs were still grounded either in DOS or BASIC, these new machines were hardware-optimized to use a desktop—unlike the existing micros and PCs that lost substantial performance when faced with a graphical environment. These machines provided powerful graphics and sound when PC equivalents were primitive or expensive. People who'd never owned a computer before—especially creative types—were now taking a look.

## MULTIMEDIA FINDS ITS NICHE

Both machines were famous for their multimedia capabilities: The Atari for its music sequencing, and the Amiga for its graphics and video processing, though there is plenty of great multimedia software on both machines.

Even though the ST had a cheap and nasty sound chip, Atari had the inspired idea of installing MIDI ports as standard—something that only cost 75 cents per machine but established Atari's niche in the music world.

Plugged into external MIDI equipment, the ST truly shined, with an excellent graphical interface and better latency than a lot of pro equipment. Programs like Cubase started on the ST, and its MIDI functionality are still used by top musicians.

As for the Amiga, audiences were wowed by drawing utilities such as Deluxe Draw, which had animation capabilities that became the industry standard in gaming, most notably by Lucas Arts with its *Monkey Island* series.

Deluxe Video created slideshows long before PowerPoint, and were the height of sophistication in office presentations. Disney had its own software suite that allowed rapidly produced animations.

For only $2,399, 1990's Video Toaster used the Amiga's ability to sync with video timing to create a video-effects suite that rivaled the machines of television stations costing more than $100,000.

Both computers had a decent gaming scene, but the Amiga's dedicated graphics and audio made it a natural fit for the multimedia demo scene that is still active today, where coders would continually search for new hardware exploits in order to make the most spectacular presentations.

**The non AZERTY Minitel TELIC-1 launched in 1985.**

**The Amiga won out over the Atari ST, with better gaming and multimedia, but the ST had its own victories with musicians and office workers.**

© WIKIPEDIA

## WHAT ABOUT TODAY?

Despite being decades out of manufacture, both machines are still popular and survive in some form, with very active communities. With the MIDI standard being so universal, an Atari ST should still be able to be used with much of today's musical hardware, and is used by the likes of Fat Boy Slim.

The Amiga also lives on through FPGA recreations and archives. If you want to use an Amiga desktop and apps on modern hardware, the open-source project AROS ports AmigaOS to x86 platforms, PowerPC, and the Raspberry Pi.

## THE MINITEL: THE INTERNET BEFORE THE INTERNET

In the 1970s, the French government decided to radically overhaul its telecommunications network. France's telephone network was considered the worst in the industrialized world. Meanwhile, French offices were filling up with American-branded computers and software bundles.

Recognizing a potential crisis, French president Valéry Giscard d'Estaing acted on a report "The Computerization of Society", by Simon Nora and Alain Minc. Given that the phone network already needed overhauling, the government saw the chance to put France at the head of the computing revolution by layering computerized services over its new phone network. This would be accessed by a standardized terminal. First and foremost, this terminal would act as a replacement for the traditional telephone directory, but the government also saw the potential for monetized services.

Work began in 1978, and the first experimental models were rolled out in 1980. Dubbed the Minitel, early models were freely available, with a nine-inch CRT monochrome display and AZERTY keyboard.

Minitel machines were mostly dumb terminals that could use text-block characters to create rudimentary graphics. Rather than acting as independent computers, the machines were really powered by dialing into a PAVI: A Point d'Accès Vidéotexte—or videotext access point in English.

## THE MINITEL TAKES OFF

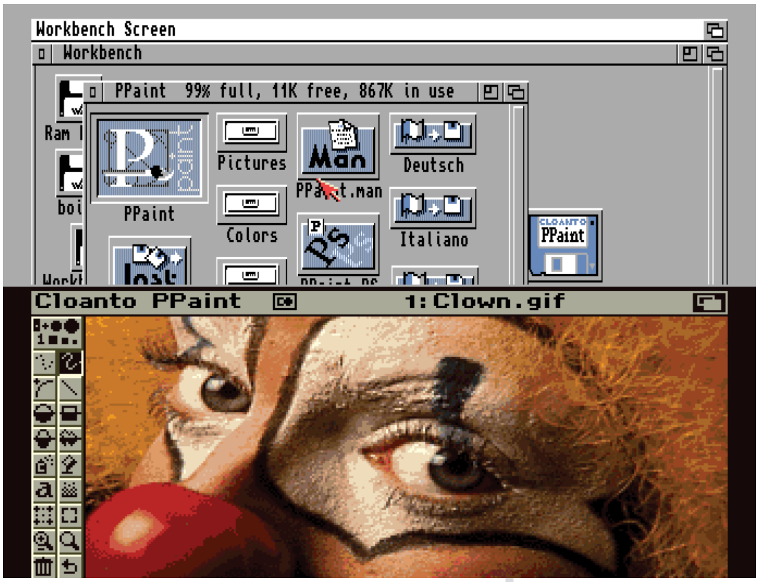
While other nations had installed similar services, such as Ceefax in the UK or Telidon in Canada, these were never exactly mainstream. In France, however, the Minitel would quickly become a national phenomenon.

The Minitel was very simple to operate, and users found its phone directory service much faster than navigating a phone book. Customers were treated to mail and chat services a decade before these were commonplace via the web.

Colorful advertisements showed how users could do banking, buy cinema tickets, or even book a holiday, and French consumers adopted the machines en masse. At its peak, the Minitel had over 26,000 services available.

Where we now think of websites in terms of .com domains, street billboards would advertise Minitel services with a famous 3615 dial prefix, such as 3615 FOOT for soccer news.

© WIKIPEDIA /RAMA, NEIL @ RMC

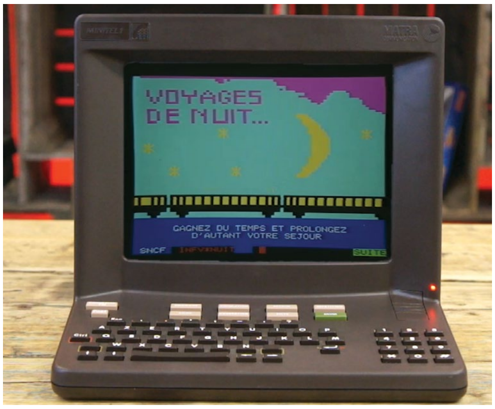


In true internet style, the Minitel system had online dating and a myriad of adult chat rooms. It was also popular for downloading public domain software: It was cheaper than connecting to bulletin board systems, or even the early World Wide Web, and faster than waiting for floppies in the mail.

Students organized protest movements through the Minitel in a similar way to how social media is often used now. And much like today's services that assume you have some kind of social media account or email address, eventually the only possible way to enrol in university was via Minitel.

The Minitel was eventually overtaken by the World Wide Web, but there was a long period in France where certain services were still only available by Minitel, until these were eventually migrated to the web. During the transitory period, some services may have had an official website, but required booking or enrolment through the Minitel.

The Minitel was an incredible success, with over 9 million units in use during the 90s, generating 832 million Euros in 1998, and was still making 30 million Euros in 2010. 810,000 terminals were still used when the service was canceled in June 2012.



**Unlike today's web, privacy around user data was heavily guarded.**

### VIRTUAL DESKTOPS

**Amiga Workbench had two ways of navigating between desktops. The first was with keyboard shortcuts, where you could drop back to the main workbench and launch more apps. But it was the second method that is truly uncanny.**

**Amigas could "screen drag" by holding down the Amiga button while clicking and dragging the mouse. Whatever screen was on display would be pulled down to reveal whatever desktop or app was behind it. A button called a "depth gadget" could put desktops or apps ahead or behind each other.**

**This looks cool now, but was absolute witchcraft in the 80s, and looks amazing when multi-tasking with full-screen video. And, due to a hardware quirk, the Amiga didn't care what resolution each app used, and could switch between them at will—something not even modern computers can do.**

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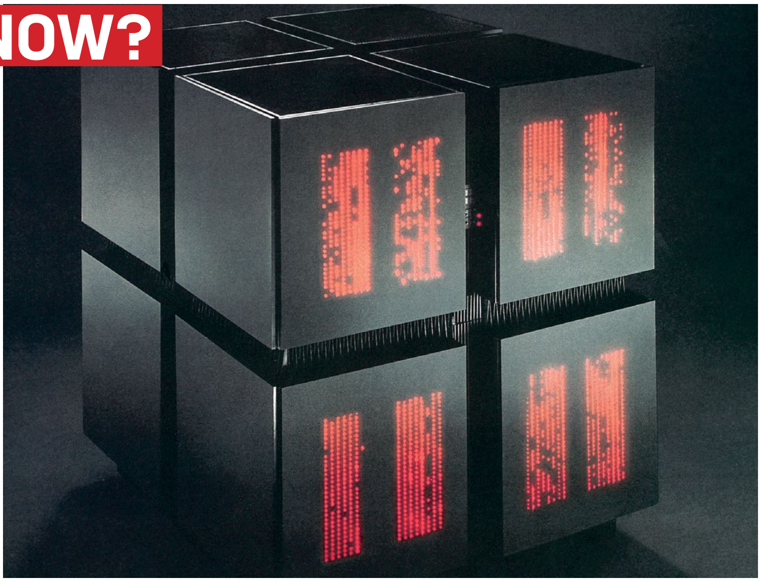
# WHERE ARE WE NOW?



**Designer Tamiko Thiel's Connection Machine line would be a key influence on Steve Jobs and kick-start sales in supercomputers.**

So, are we suggesting that things were better back in the day, and that all of today's computing power and progress has been for nothing? Well no, that would be ridiculous. But although our machines are now many thousands of times faster, we don't have thousands of times the results—certainly not the kind of results we would have predicted in earlier decades.

Compare the last 10 years with the 80s. In two years we went from the Commodore 64 to the Amiga—an entire generational jump, involving machines at the top of their game. In the same year the PC went 32-bit with the 386. They started the decade with kilobytes of RAM, and ended it instead with megabytes.

We like to laugh at movies' predictions from the 80s and 90s, where everyone would have flying cars by now, and virtual reality had replaced the keyboard and mouse. But if you look at the astonishing rate of technological progress during those decades—and assuming that the same rate of progress would continue—then those predictions would have been quite rational. In many ways progress has slowed down. Changes are now evolutionary rather than revolutionary.

In the 80s, a few years between games would result in tangibly different results, and the difference between 1980 and 1990 was enormous. But compare games from 2010 and 2020, and they aren't radically different experiences.

We use enormous operating systems to achieve tasks that are largely similar to those of the 80s and 90s. But where modern computers are a noisy mess of pop-up warnings, updates, and error messages, older computing is often simpler and quieter, with fewer distractions.

Sometimes it's quicker and more responsive too. Competition gamers often use PS/2 peripherals—a standard from 1987—or old consoles with CRT televisions, especially with *Tetris* and *Street Fighter II*. Reactions count, and USB and HDMI have lag.

## SO WHAT HAS GONE WRONG?

A big difference between then and now is the luxury of raw computing power—it seems that any problem can be solved by throwing more RAM and CPU cycles at it. This has resulted in very high-level programming, where programming used to be much closer to the metal.

On the one hand, this extra computing power has brought programming to the masses—there's even a growing no-code movement—but on the other hand, our code has become wasteful and inelegant, requiring enormous resources for even basic tasks. A modern web browser consumes a gigabyte of RAM even if a website is only kilobytes in size!

## WHAT WE CAN LEARN?

Be careful with the word "obsolete." Newer doesn't necessarily mean better, nor more advanced. You may have the latest hardware, but does that necessarily make it fit for purpose? Could an older kind of technology achieve better results than what you're using now?

Computing history contains many brilliant technologies that have been lost along the way, but if today's engineers are willing to explore methodologies or form factors that have fallen out of favor, it may enable current technologies to make sudden leaps forward.

IT departments may also consider hiring older programmers and engineers to optimize code and bring different perspectives. What may take a team of younger coders a day in a visual-programming environment may be solved in two minutes by a Unix veteran with a terminal.

Older programmers may also be able to take code in very high-level languages and re-apply the algorithms in a lower-level language like C, or maybe even Assembly! Likewise, older engineering methods could provide simple and effective solutions to problems flummoxing younger engineers, who may only have been exposed to current technology. ⏻

**The Raspberry Pi 400 has been hailed as a revolutionary new keyboard computer, when it's actually a return to the microcomputer form factor.**

## RASPBERRY PI TO THE RESCUE

**Raspberry Pi founder Eben Upton started the project after seeing an alarming drop in coding proficiency with university applicants. With an extremely cheap machine, it was the foundation's intention to get children coding again, the way 8-bit microcomputers started bedroom coding in the 80s.**

**The default Raspberry Pi OS comes loaded with programming languages, environments, and interpreters, though there has always been a focus on Python—perhaps the best modern equivalent of BASIC. GPIO pins are displayed, making the machines perfect for hardware hacking.**

© HINKING MACHINES CORPORATION, 1986. PHOTO: STEVE GROHE, RASPBERRY PI FOUNDATION

# TECH PORN

PERFORMANCE GEAR LAID BARE

# HP S430c 43.4-inch Curved Ultrawide Monitor

**THERE'S SOMETHING** to be said for a screen like this. It's without doubt a bit of an oddball. There's a flow and elegance to it—it's big, bold, extravagant, and beautiful—and yet its purpose is singular. It has one target audience, and although it excels very well in that area, it excels only in that area.

This is, for all intents and purposes, a workstation screen, designed with the productivity clan in mind. It is flawless when looking at it from inside the business world, yet uniquely flawed in its dogmatic approach to appeasing that market.

The price? $999. That crisp, succinct number is a figure itself attuned to marketing standards to elicit a "cheaper than it really is" feel. A sheep in wolf's clothing then? Perhaps. But if ultimate productivity and solid reliability are what you crave, then the HP S430c masterfully checks all of those boxes with panache. **–ZAK STOREY**

### 1 PRODUCTIVE PIXEL DENSITY

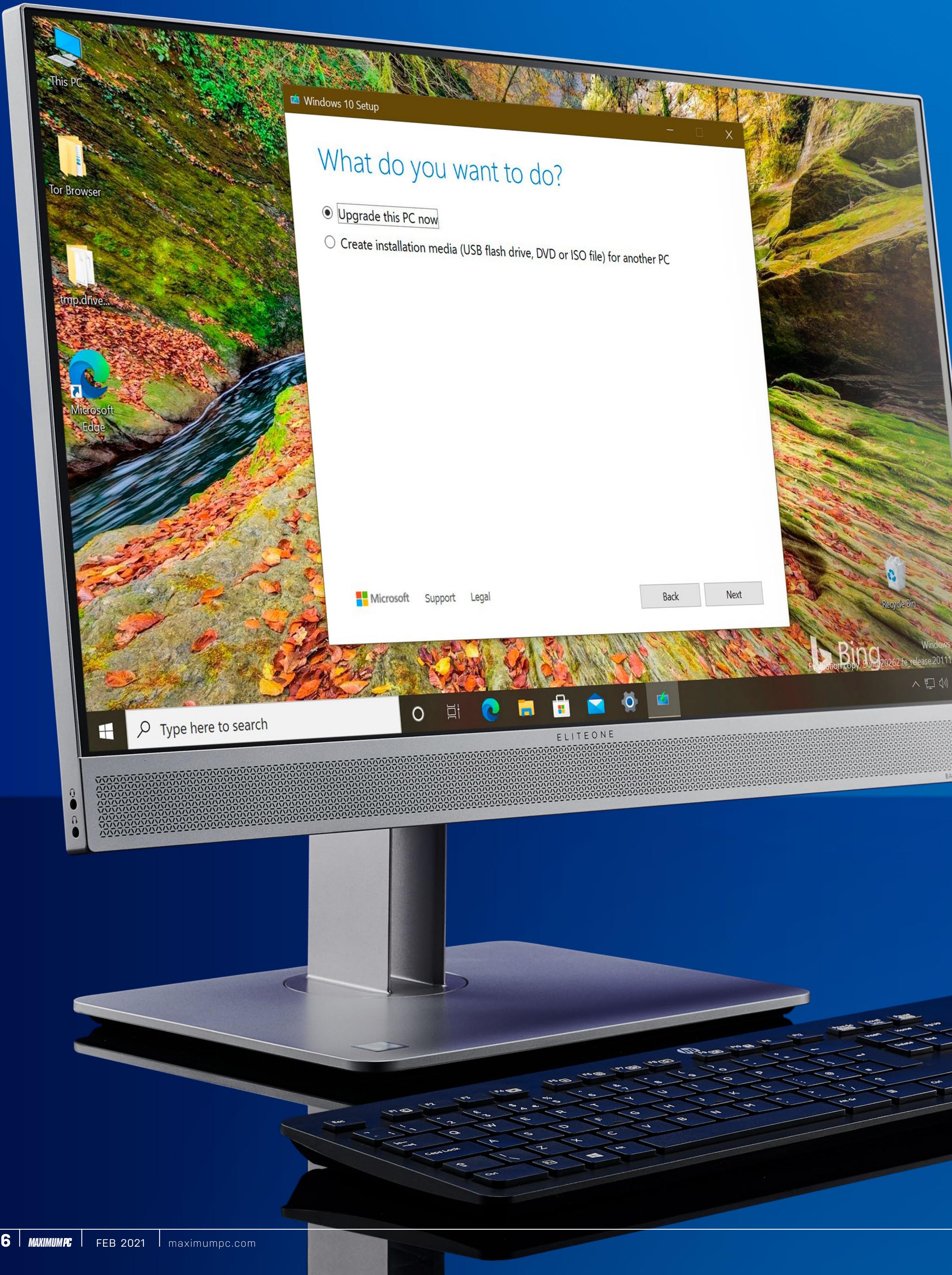
The S430c has a pixel density of just 92.7PPI. That's because it's effectively two traditional 1080p panels stitched together, and they can be used as such too, showing two devices on one screen at the same time.

### 2 USB TYPE C POWERHOUSE

It also packs in USB Type C connectivity as standard. There's two ports, so you can plug this straight into your MacBook or Dell XPS without worry, enabling display, power (65W), and USB connectivity. It also features DisplayPort 1.2, HDMI 2.0 (with HDCP), and four USB 3.1 ports.

### 3 WEBCAM BRILLIANCE

On top of all of those "no-nonsense" productivity frills, it also comes with an integrated webcam. This is a full 1080p affair with dual microphones, and can be hidden by popping it down from on top of the screen itself. It also has support for Windows Hello's Facial Recognition login software solutions, for if you want to take it even further.



Windows 10 Setup

What do you want to do?

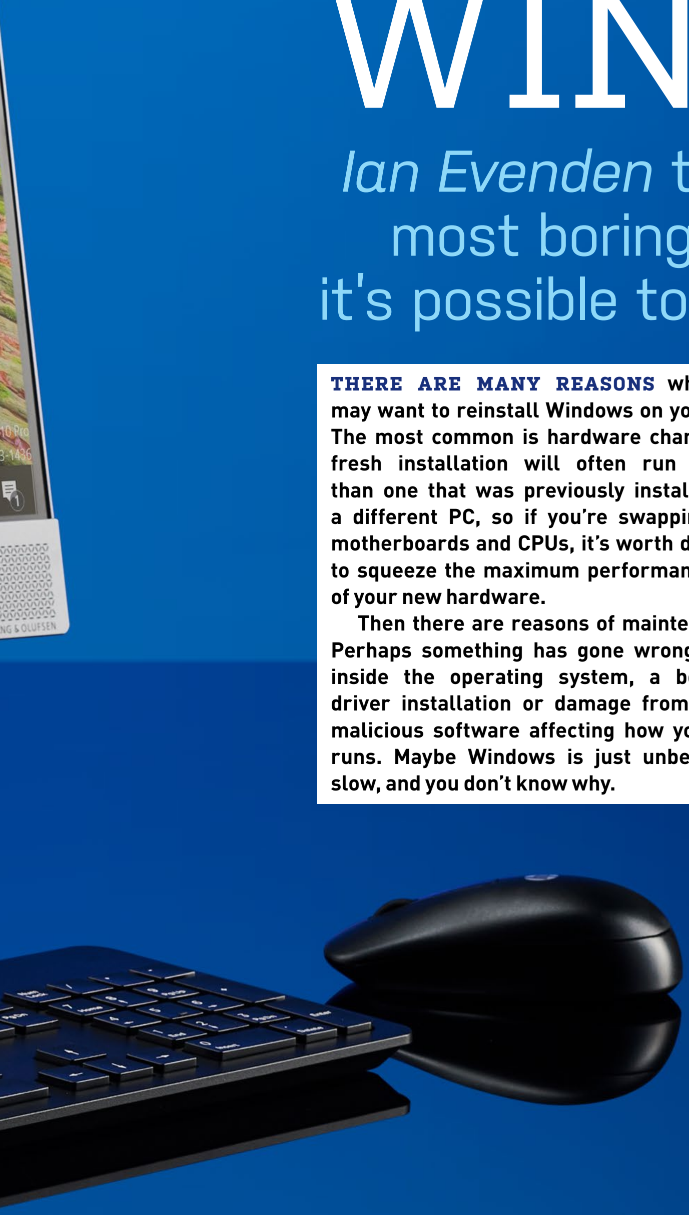
● Upgrade this PC now

○ Create installation media (USB flash drive, DVD or ISO file) for another PC

This PC
Tor Browser
tmp.drive...
Microsoft Edge
Microsoft
Support
Legal
Back
Next
Recycle Bin
Bing
Type here to search
ELITEONE

# THE ULTIMATE GUIDE TO
# REINSTALLING WINDOWS

*Ian Evenden* takes on possibly the most boring yet essential task it's possible to carry out on your PC



**THERE ARE MANY REASONS** why you may want to reinstall Windows on your PC. The most common is hardware change—a fresh installation will often run better than one that was previously installed on a different PC, so if you're swapping out motherboards and CPUs, it's worth doing it to squeeze the maximum performance out of your new hardware.

Then there are reasons of maintenance: Perhaps something has gone wrong deep inside the operating system, a botched driver installation or damage from some malicious software affecting how your PC runs. Maybe Windows is just unbearably slow, and you don't know why.

All of these are good reasons to reinstall Windows, and it's a quick and easy process these days. And while a complete reinstall is your nuclear option, wiping away all traces of what came before, there are other options—Reset and Refresh—that can help you out too, saving your documents if you're not so hot on the backup regime.

Here is not a discussion of why you should reinstall the OS—you'll know when the time is right—but how to do it. While there are different methods, they all rely on being able to download the OS from Microsoft's servers, so you'll need a PC with an internet connection. Do not let your PC get so bad that you can't fire up a web browser!

## GETTING STUCK IN

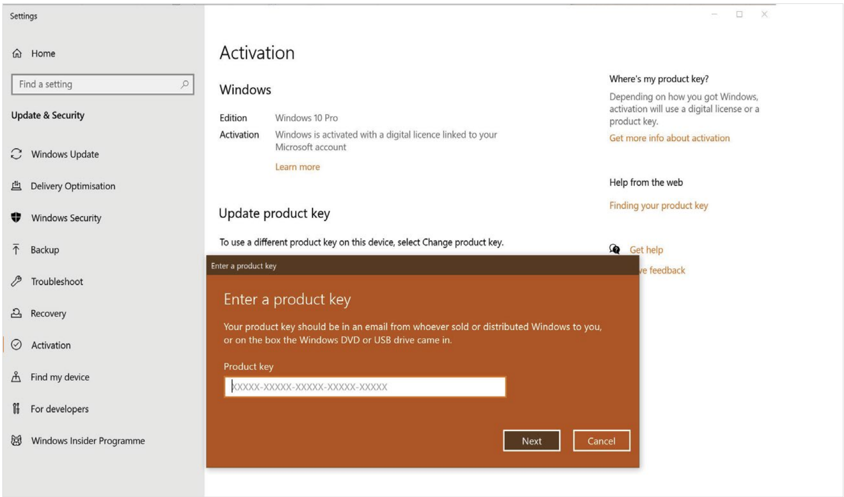
If you need to completely wipe your system and start again, there's a bit of work to do first. You'll need a Windows PC, a USB stick that's 8GB or larger (or a blank DVD-R in a writable drive), and the Media Creation tool from www.microsoft.com/en-us/software-download/windows10. Run it, choose "Create Installation Media..." and follow the prompts.

When it comes to a full reinstall of Windows 10, you will need your product key, or at least a digital license linked to your Microsoft account. Check "Settings → Update & Security → Activation." If you see the message "Windows is activated with a digital licence," this means you're digitally signed, but you should link that license to your Microsoft account in case of installation issues or future hardware changes. Head to "Settings → Accounts → Your Info," sign in with your Microsoft account details, and the message should change to "Windows is activated with a digital licence associated with your Microsoft account."

It's also worth making a note of any product keys for your software—you can create a list of all the programs installed on your PC with a Powershell command. Run it as an administrator, and type:

```
Get-ItemProperty HKLM:\Software\
Wow6432Node\Microsoft\Windows\
CurrentVersion\Uninstall\* | Select-
Object
DisplayName, DisplayVersion,
Publisher, InstallDate | Format-Table –
AutoSize > C:\software.txt
```

This creates a file called software.txt in the root of your C drive with a list of all your installed programs, so when you come to reinstall them you won't forget one.



Activation

Windows

Edition Windows 10 Pro
Activation Windows is activated with a digital licence linked to your Microsoft account
Learn more

Update product key

To use a different product key on this device, select Change product key.

Where's my product key?
Depending on how you got Windows, activation will use a digital license or a product key.
Get more info about activation

Help from the web
Finding your product key

Enter a product key

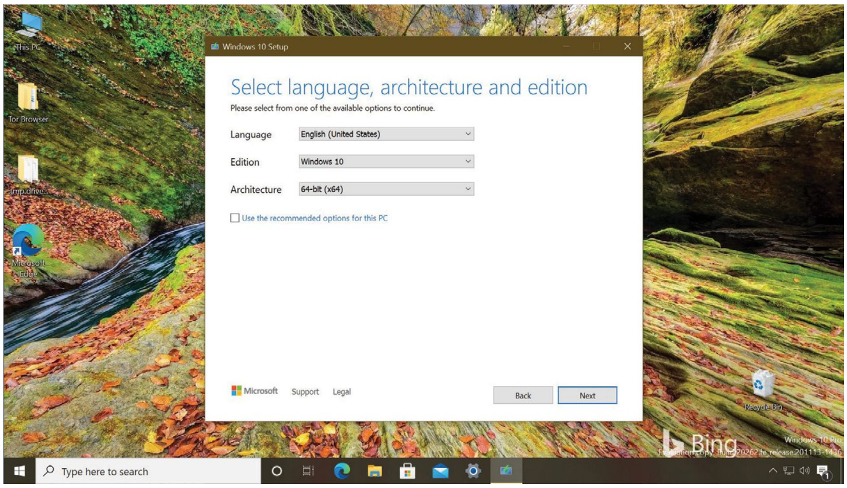
Your product key should be in an email from whoever sold or distributed Windows to you, or on the box the Windows DVD or USB drive came in.

Product key: XXXXX-XXXXX-XXXXX-XXXXX-XXXXX

**Enter the Windows product key to link that license to your account.**

Third-party freeware app ProduKey (www.nirsoft.net) will dig out your Windows product key and those for many other programs. However, both Windows 10 and Malwarebytes flag it as potentially harmful, and Windows refuses to run it, so we couldn't possibly tell you to go to "Windows Security" in "Settings," then choose "App and Browser Control" to allow it to run anyway. That's at your own risk, obviously. Also, consider using a password manager to safely hold all your passwords, so you don't need to worry about any that are stored on your PC getting lost. We like Bitwarden, as it's open source and free.

The last thing to do, if you've not been doing it all along, is to get backed up. While it's possible to do an upgrade in place of Windows 10, retaining all your documents but replacing the OS and losing your apps, it's not a 100-percent foolproof process. Take a backup just in case. At the very least, shove all your documents onto an external drive, as losing precious digital memories can be heartbreaking.



Select language, architecture and edition

Please select from one of the available options to continue.

Language: English (United States)
Edition: Windows 10
Architecture: 64-bit (x64)

☐ Use the recommended options for this PC

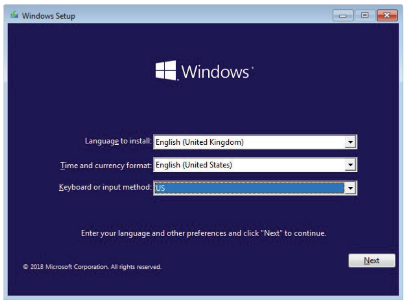
**Use the Media Creation tool to create installation media for Windows 10.**

## IN MEDIAS RES

By now, the Media Creation tool should have downloaded Windows 10 and be creating your installation media. The process is completely automatic, so you don't have to do anything except watch the progress percentage get higher and higher. Eventually you'll get a message saying that your USB flash drive is ready, and a "Finish" button. Click it, and the installer cleans up after itself and exits. You're left with a bootable USB drive that you can use in a few different ways.

Firstly, you can use it to perform an upgrade to your current machine. Double-click the Setup file on your installation medium, and you'll be taken to the Windows 10 set-up app, which will install the OS over the top of whatever you're running. You've made your install medium from the latest version, but it checks for updates anyway, before asking you what you'd like to keep. This is important, as it determines the extent of the cleansing that's about to happen to your system.

Choose to "Keep personal files and apps" if you want to come back to a PC that hopefully functions better than before, but looks much the same and still has all the same apps installed on it. "Keep personal files only" is a deeper wipe that takes out all your apps but retains your documents. "Nothing" is the scorched-earth option—a good choice if you're reinstalling before



Windows Setup

Language to install: English (United Kingdom)

Time and currency format: English (United States)

Keyboard or input method: US

Enter your language and other preferences and click "Next" to continue.

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**Going through the Windows setup gives you the chance to select language, etc.**

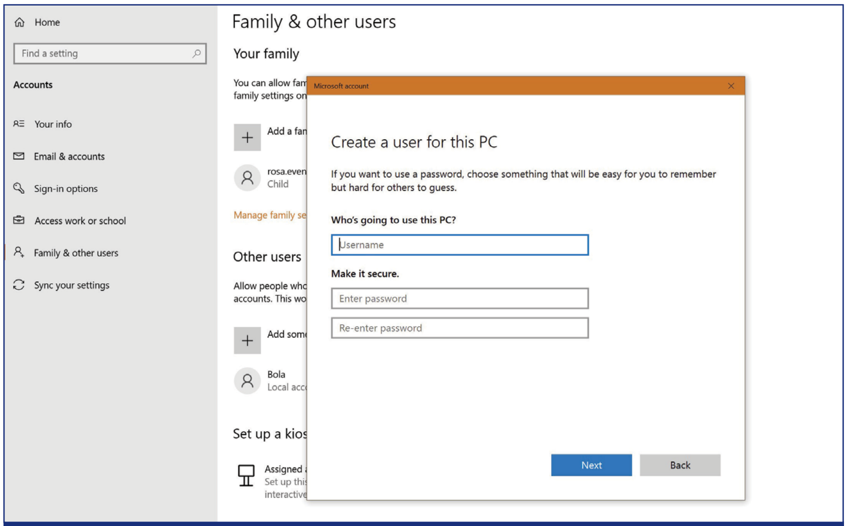
selling your PC. It leaves nothing behind but the OS and the smell of recently deleted files.

Whichever of these you click, there's a brief pause while it checks for yet more updates—presumably in case Microsoft snuck one out while you were pondering what to keep—before giving you the chance to review your choices one last time. Pressing the "Install" button from the "Ready to install" screen begins a process there's no way back from.

The other thing you can do with the installation medium you've prepared is to stick it into another PC and use it to upgrade that machine. While the USB stick or DVD you prepared is bootable, you'll almost certainly need to tinker in the BIOS of the target machine to make sure it looks for another bootable drive before booting from its C drive. Getting into the BIOS is usually a matter of hammering Del or F1 while it POSTs, but different manufacturers make their BIOSes differently, so we have little advice to offer on changing the boot order. Just have fun poking around in there, and try not to break anything.

## RESET OR REWIND

A reset is an easier way to do all we've done above, just without creating the useful installation medium. Resetting only gives you two of the options you got with an in-place upgrade: Keep your files, or keep nothing. There's no "keep apps" option here, so if that's important to you, you'll need to do the reinstall through the installation medium method. You're offered the choice of a cloud download of the most recent version of Windows 10, or using the version already on your PC. We'd recommend the cloud download unless your PC is not online or using dial-up. It's going to download more than 4GB,



Family & other users

Your family

You can allow fam
family settings on

Add a fam

rosa.even
Child

Manage family se

Other users

Allow people who
accounts. This wo

Add som

Bola
Local acc

Set up a kios

Assigned
Set up this
interactive

Microsoft account

Create a user for this PC

If you want to use a password, choose something that will be easy for you to remember but hard for others to guess.

**Who's going to use this PC?**

Username

**Make it secure.**

Enter password

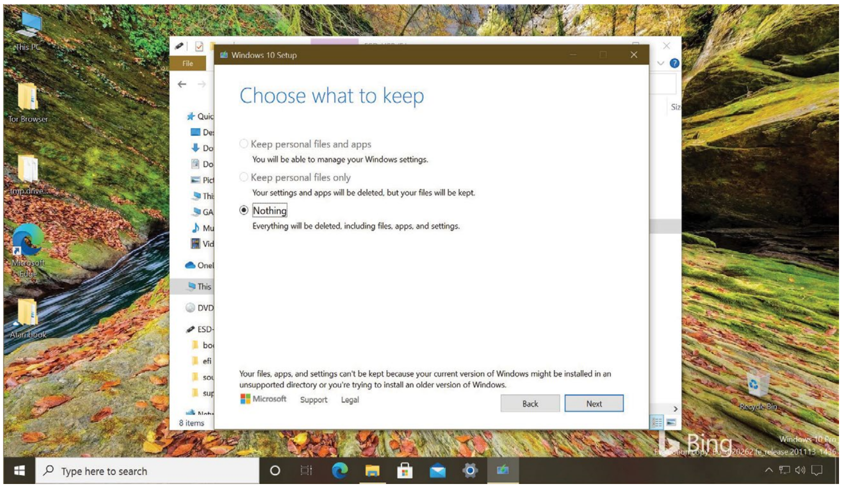
Re-enter password

## LOCAL ACCOUNTS

**Creating a local account, as opposed to a synced Microsoft account tied to an email address, used to be the default way of accessing an operating system. Microsoft is trying to change all that with Windows 10, however, and is pushing the Microsoft account hard, to the extent of removing the option to create a local account during installation. This makes sense, as the account you made during setup is the PC's admin account, and so needs to be secure.**

**The option is still there though, albeit buried. Open "Settings → Accounts → Family & other users," and choose "Add someone else to this PC." Click "I don't have this person's sign-in information" in the window that pops up, then "Add a user without a Microsoft account" in the next one. Finally, you'll be able to add a user account to the computer without tying it to a Microsoft account. You will be asked for the name and a password, but only the name is needed—it's perfectly possible to create an insecure password-less account, and also possible to change its account type from standard user to admin without adding a password. We really, really don't suggest you do this, as it leaves a large security hole that is easily exploited.**

**Local accounts can be converted to Microsoft accounts later from the same screen, while the main admin account you created during installation can be converted to a local account from "Settings → Accounts → Your info."**



Windows 10 Setup

Choose what to keep

○ Keep personal files and apps

You will be able to manage your Windows settings.

○ Keep personal files only

Your settings and apps will be deleted, but your files will be kept.

● Nothing

Everything will be deleted, including files, apps, and settings.

Your files, apps, and settings can't be kept because your current version of Windows might be installed in an unsupported directory or you're trying to install an older version of Windows.

**You can select how much of your current system you wish to keep.**

© MICROSOFT

however. Note that if you've recently updated, you won't be able to roll back that update after you've finished the reset. This can be crucial if it's a recent update that's causing you a problem. Hit "Next," and you'll be offered one last chance to review your choices, before hitting the "Reset" button and letting it do its thing.

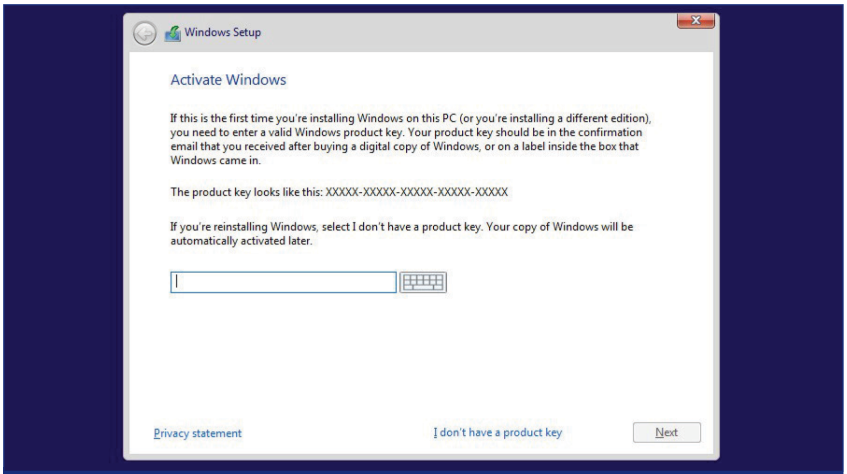
If you've recently updated your Windows 10 installation to the latest version, and feel it's not working out or could do with some more development time, you can roll it back. You can do this from two places, depending on the state your PC is in. Either in "Settings → Recovery" (you have to be within 10 days of the offending update's installation, otherwise the option isn't available), or by booting from an install medium and choosing "Repair your computer" from the "Install now" screen.

Clicking this option gets you some interesting new toys to play with. You can restore from a Restore Point, should you have one saved on your PC, and you can reinstall Windows from a specific disk image, or use Startup Repair to fix problems that prevent Windows from loading. But we came here for uninstalling problem updates, and the option is right there on the left. Click it, and you get further choices—the last quality update, or the last feature update. Quality updates tend to be bug fixes or security patches, while feature updates are the bigger releases, such as the October 2020 update. Select the option you think is causing the problem, and hit the button to uninstall. There's still a chance it won't be able to roll it back, especially if it's been installed for a while, but it's worth a try.

## REBUILD, REMAKE

Back to our reinstall, and note we're using the October 2020 update version of Windows 10 Home, as that's what was available at the time of writing. If you're reading this in the future, 1) Hello! How are the flying cars? 2) Your experience of installing Windows 12 onto a quantum PCIe 6.2 SSD may be different.

Once you've booted from the USB drive, you're presented with a screen that has a big, friendly "Install" button, and the much smaller repair option. Hit "Install," and you'll be prompted to choose your PC's language and keyboard layout. The next screen is for activation. If you have it to hand, you can put in your product key now and click "Next," otherwise click "I don't have a product key" at the bottom. Both have the same effect—the reinstallation



Activate Windows

If this is the first time you're installing Windows on this PC (or you're installing a different edition), you need to enter a valid Windows product key. Your product key should be in the confirmation email that you received after buying a digital copy of Windows, or on a label inside the box that Windows came in.

The product key looks like this: XXXXX-XXXXX-XXXXX-XXXXX-XXXXX

If you're reinstalling Windows, select I don't have a product key. Your copy of Windows will be automatically activated later.

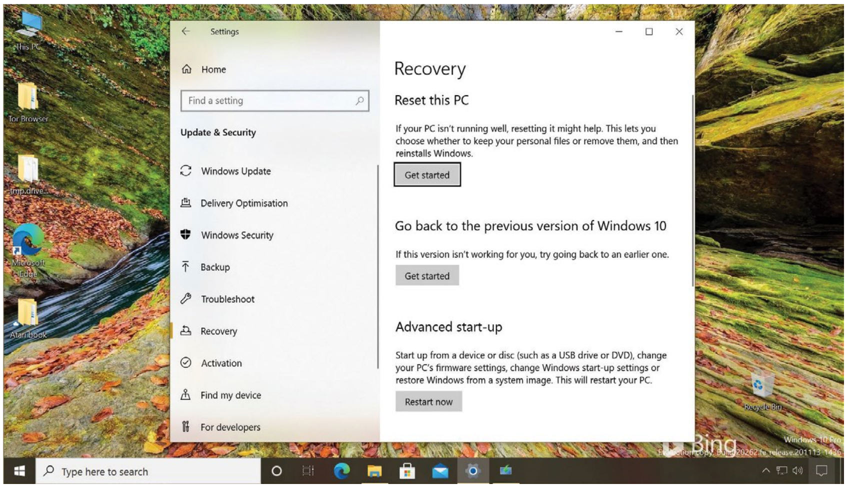
## WINDOWS ACTIVATION

**Windows activation is a kind of super fun thing that, if it goes wrong, shows you really unhelpful messages and gets you to phone Microsoft support. However, if you didn't have a licence key to type in during installation, and this is a reinstallation onto a system that's been activated and tied to a Microsoft account before, there is one thing you can do. On the "Settings → Update & Security → Activation" page, click "Troubleshoot." You must be logged into your Microsoft account for this to work, and it needs to be the same one that was previously activated.**

**The troubleshooter thinks for a while, then gives you a list of the Windows activations registered to your account. Click the one you want to use, and the "I've recently changed hardware" box if necessary, and activation will often complete.**

**If you've purchased Windows online, your product key can be found in the confirmation email. Sometimes it's printed on a sticker fixed to the bottom of laptops.**

**However, not activating Windows—despite activating being unequivocally the right thing to do—doesn't really limit its use. You get a watermark in the bottom right of the screen saying it isn't activated, and you're prevented from changing the wallpaper away from the blue Windows logo using "Personalize" (but can still change it with right-click → Set as desktop background). Otherwise, it doesn't nag you. This may change, but for now there's little penalty to not activating, apart from the disintegration of your soul. You can pay to activate at any time, should the guilt become too much.**



Recovery

Reset this PC

If your PC isn't running well, resetting it might help. This lets you choose whether to keep your personal files or remove them, and then reinstalls Windows.

Go back to the previous version of Windows 10

If this version isn't working for you, try going back to an earlier one.

Advanced start-up

Start up from a device or disc (such as a USB drive or DVD), change your PC's firmware settings, change Windows start-up settings or restore Windows from a system image. This will restart your PC.

**There are several options to reset or recover Windows.**

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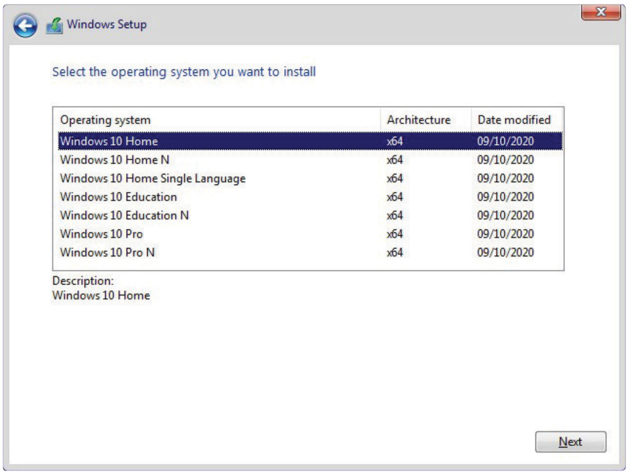
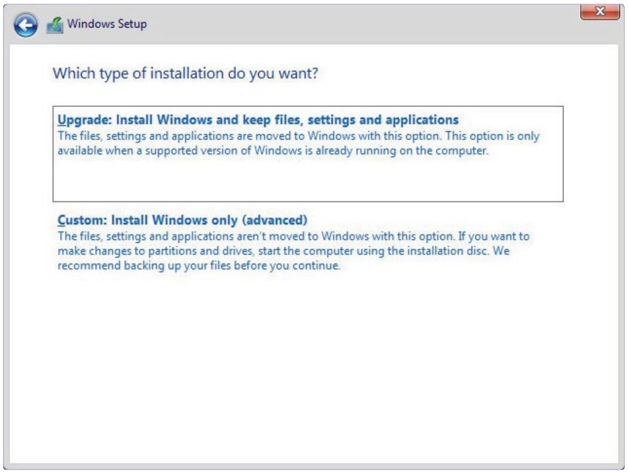


Select the operating system you want to install

| Operating system | Architecture | Date modified |
|---|---|---|
| Windows 10 Home | x64 | 09/10/2020 |
| Windows 10 Home N | x64 | 09/10/2020 |
| Windows 10 Home Single Language | x64 | 09/10/2020 |
| Windows 10 Education | x64 | 09/10/2020 |
| Windows 10 Education N | x64 | 09/10/2020 |
| Windows 10 Pro | x64 | 09/10/2020 |
| Windows 10 Pro N | x64 | 09/10/2020 |

Description:
Windows 10 Home

**Choose the Windows version that exactly matches your product key.**



Which type of installation do you want?

Upgrade: Install Windows and keep files, settings and applications
The files, settings and applications are moved to Windows with this option. This option is only available when a supported version of Windows is already running on the computer.

Custom: Install Windows only (advanced)
The files, settings and applications aren't moved to Windows with this option. If you want to make changes to partitions and drives, start the computer using the installation disc. We recommend backing up your files before you continue.

**Choosing "Upgrade" will begin the installation process.**

continues—but if you choose the latter you'll need to activate Windows later.

At the next screen, choose which version of the OS you'd like to install. This should exactly match the version your product key is for, or the version you intend to buy later. Most of the time it'll be Home, although the Pro version is often available cheap online and gives access to interesting features, such as the built-in hypervisor, or BitLocker encryption. The "N" versions of Windows don't come with certain apps such as Skype, Windows Media Player and the voice recorder. The N versions are only for sale in Europe, while a KN version is for South Korea, and they exist purely for tedious legal reasons involving court rulings from 2004 (2005 in South Korea). If you see either of these versions, feel free to ignore them. Even if you're in one of the affected jurisdictions, you don't have to install an "N" version—the usual version is available too.

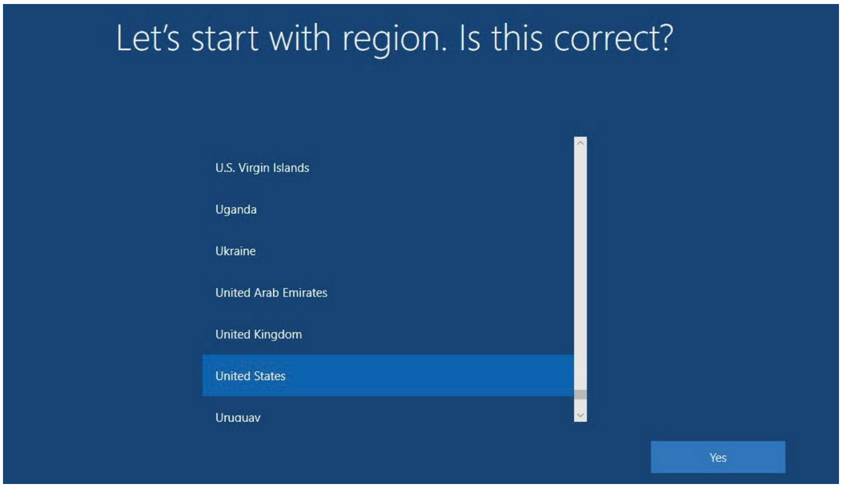
Pick your version, hit "Next," accept the license terms, and you're faced with another choice: Upgrade (only works if there's already a copy of Windows installed on the PC, and keeps your files, settings, and applications) or "Custom." The latter is for machines without an installed OS, or if you want a completely destructive reinstall. It lets you format the disk partition you'll be installing onto, and completely sets up your PC as if it was new. If you choose "Custom," you are happy with the way your drives are set up and have clicked on a partition to receive the OS, the very next screen once you press "Next" begins copying files for the installation. The only way back from here is to use the red X button to cancel, and begin the process all over again.

Hit "Next," however, and you might as well sit back and have a coffee. The installation process from a USB drive is fast and doesn't call on you until it's time to create an account and sign in for the first time. It's also relatively fast, especially if you can recall installing Windows XP from CD, or 3.1 from floppies. It restarts a few times, and it's not long before you're facing the terrifying words: "Hi, I'm Cortana, and I'm here to help." Ignore her, unless you need assistive technology, and go on to select your region and keyboard layout.

You'll be left waiting a few times during this setup process, but the next screen asks you to create an account. It wants an email address, Skype ID, or phone number to create a Microsoft account. Where once you could create a local account and access the OS the old-fashioned way, now you have to sign into a Microsoft account the first time you use it. You can create a local account later—see "Local Accounts" on page 49. Give your MS account address and password, and you'll be prompted to choose a PIN for Windows Hello.

Next you're into privacy settings. If you're not sure what to choose when confronted with the wall of privacy settings, then it pays to err on the side of caution. If you've locked off something you later decide you can use, then it's possible to change a setting later. The only ones we leave on are "Find My Device," and "Location Services," just in case we lose our PC somewhere. Next, you're asked to connect an Android phone to see your texts and notifications appear as Windows notifications, but you can hit the "Do it later" button to skip this step.

Next is OneDrive. There's a button in the bottom-left corner of the screen that lets you skip this step—"Only save files to this PC." Otherwise, "Next" takes you to a screen activating Cortana. You can "Accept," or say "Not Now." Eventually, after a wait of a few minutes, you'll get your desktop with an advert for Edge in the corner. The first thing to do is to change the desktop resolution to that of your monitor, and then the rest is up to you (although Ninite and driver and chipset installation is a good start!)


Let's start with region. Is this correct?

U.S. Virgin Islands
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay

**Choose your region and keyboard layout following a reinstall.**

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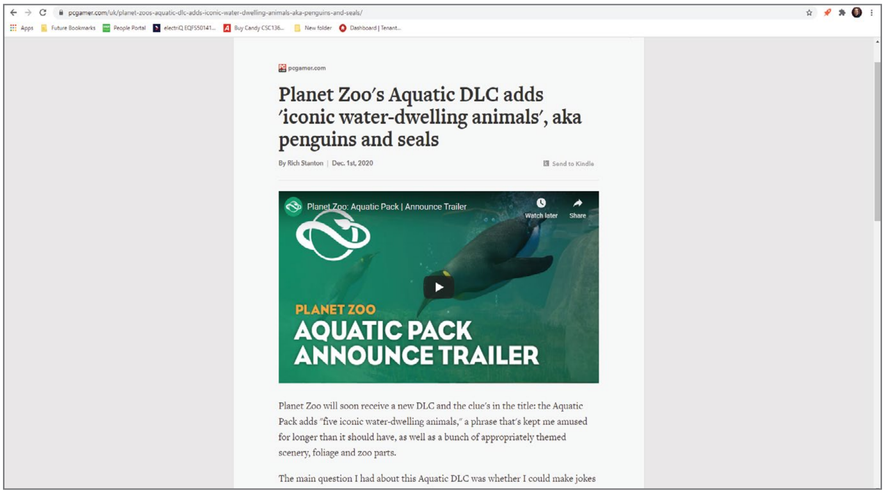
# HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

## TIP OF THE MONTH


pcgamer.com/uk/planet-zoos-aquatic-dlc-adds-iconic-water-dwelling-animals-aka-penguins-and-seals/
Apps
Future Bookmarks
People Portal
electriQ EQFS50141...
Buy Candy CSC136...
New folder
Dashboard | Tenant...
pcgamer.com
Send to Kindle
Planet Zoo: Aquatic Pack | Announce Trailer
Watch later
Share
PLANET ZOO
AQUATIC PACK
ANNOUNCE TRAILER

Planet Zoo's Aquatic DLC adds 'iconic water-dwelling animals', aka penguins and seals

By Rich Stanton | Dec. 1st, 2020

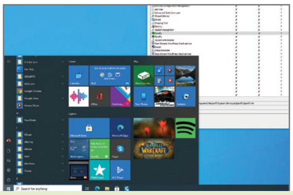
Planet Zoo will soon receive a new DLC and the clue's in the title: the Aquatic Pack adds "five iconic water-dwelling animals," a phrase that's kept me amused for longer than it should have, as well as a bunch of appropriately themed scenery, foliage and zoo parts.

The main question I had about this Aquatic DLC was whether I could make jokes

### READ EASY WITH MERCURY

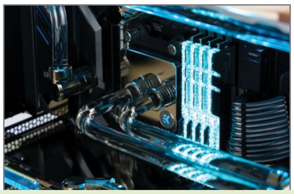
Do you read on screens a lot? We do, and we know it's bad for our eyes. Mercury Reader is a one-click Chrome extension that enables you to instantly remove the clutter from online articles for easy reading. It works a charm, and also performs well with Chrome's existing reading list functionality, making it straightforward to save multiple articles for later reading. Give your eyes a break.

## MAKE – USE – CREATE



**56**
Tidy up your screen by using virtual desktops

**62**
Emulate our Machine of the Month: the Amstrad CPC



**64**
Follow our reflections on our Mirror Maze build

© POSTLIGHT, GOOGLE

CHRISTIAN GUYTON
**STAFF WRITER**

## SIZE MATTERS

OK, so I went to the dark side and played some games on a PS5. I was seriously impressed. *Spider-Man: Miles Morales* looks and feels incredible, with load times seemingly a thing of the past and a photo mode I could spend literally hours in. It's impressively quiet, too, thanks to the passive cooling offered by its bulky chassis.

Yes, the PlayStation 5 is a big boy by console standards. Its clean, curved, black-and-white design is reminiscent of stylish gaming PCs like the Alienware Aurora R9, and the size is similar, too; it's hard to deny that these next-gen consoles are effectively gaming PCs in their own right.

Allegedly, Sony engineers wanted to make the console even larger, before presumably getting smacked by a senior sales executive who informed them that nobody owns a TV stand that big. It does make me wonder about the future of physical consoles, though. Will we see an even chunkier PS5 Pro in a few years? I almost hope so. PCs then stand to become the more popular compact option, with smart GPU mounting solutions and slick ITX cases coming into the limelight. With integrated graphics getting better and better, the potential for cheap, compact gaming machines is only growing. I can't wait to see where it goes next!

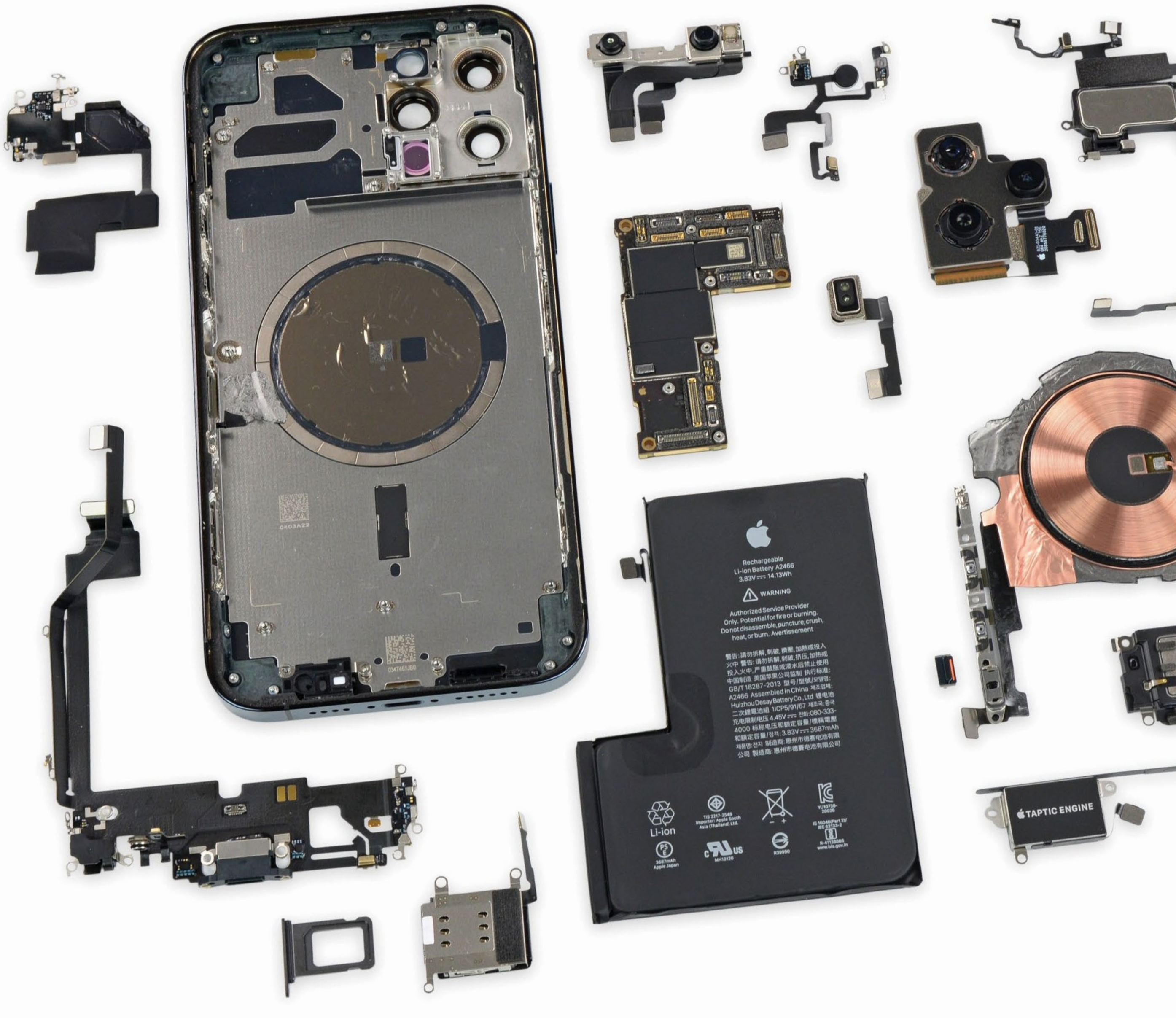
↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

# AUTOPSY

THIS MONTH WE DISSECT...

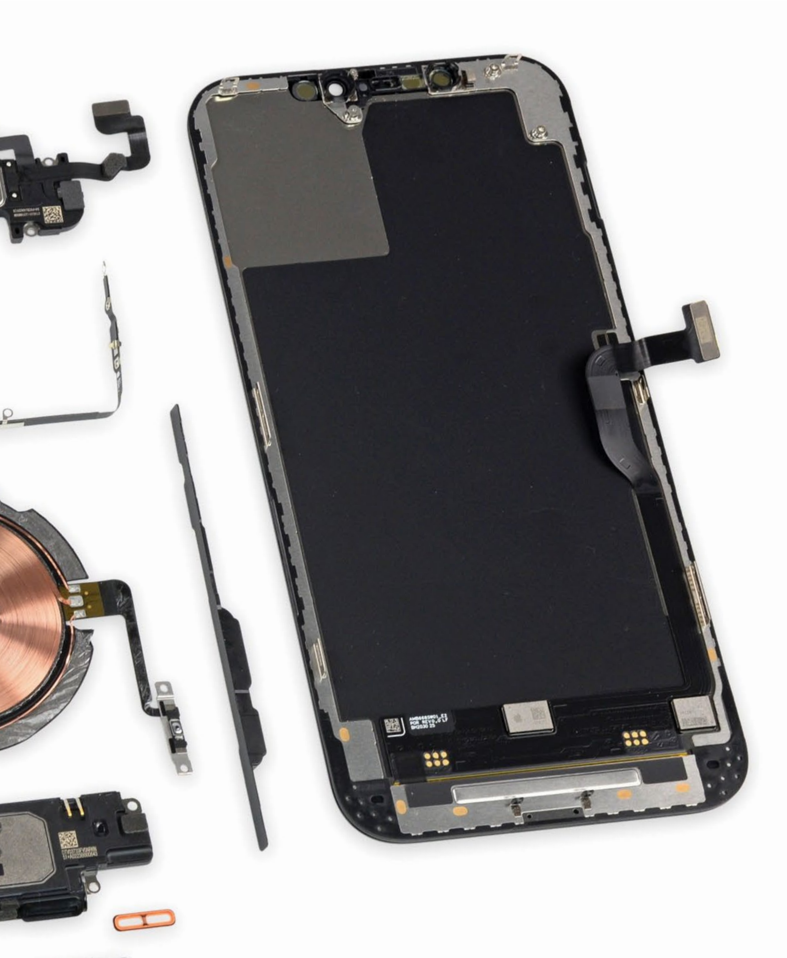
# iPhone 12 Pro Max


Rechargeable
Li-ion Battery A2466
3.83V 14.13Wh
WARNING
Authorized Service Provider Only. Potential for fire or burning. Do not disassemble, puncture, crush, heat, or burn. Avertissement
Li-ion
TAPTIC ENGINE

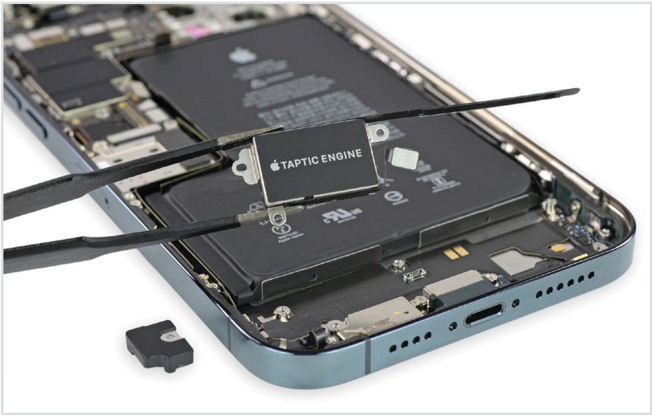
## About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.

**The basics of this iPhone look about the same as the rest of the 12 family, but the dark steel frame is Pro-only.**



**The haptic user feedback engine, the "taptic," comes in its own little metal caddy.**



## BACKGROUND

We've torn down the mini iPhone and the two medium iPhones, but we saved the biggest for last: the iPhone 12 Pro Max. Time to give this full-bodied phone the full teardown treatment.

## MAJOR TECH SPECS

- A14 Bionic SoC with fourth-generation Neural Engine
- 6.7 inch (2778x284 pixels) Super Retina XDR OLED display with P3 wide color gamut and True Tone
- 12MP triple camera with wide angle f/1.6 (OIS), ultra-wide angle f/2.4, and telephoto f/2.2 (OIS) cameras, with a LiDAR module
- 6GB RAM, 128GB storage (256 and 512GB configs available)
- 5G (sub-6GHz and mmWave), plus 4x4 MIMO LTE, 802.11ax Wi-Fi 6, ultra-wide band (UWB), NFC, and Bluetooth 5.0
- MagSafe 15W wireless charging
- IP68 rating, water resistant to a maximum depth of 6 meters for up to 30 minutes under IEC standard 60529

## KEY FINDINGS

- Sorry to break it to you, but size does matter—at least when it comes to camera sensors. To achieve its alleged 87 percent improvement in low-light performance, the 12 Pro Max uses the biggest sensor in an iPhone yet.
- A standard-issue heat and iSclack application persuades this big Pro Max to let its guard down and share some secrets. We head for the headline Pro Max feature: the new cameras. The standard wide camera (bottom-left in the group of three) is the source of all the 12 Pro Max chatter. It reportedly houses a 47 percent larger sensor, allowing it to gather more light and, thus, take better photos. With X-ray vision, we see that the standard wide's sensor is definitely bigger. We can also clearly see the four magnets surrounding it—telltale signs of Apple's brand-new sensor-shift image stabilization system.
- The iPhone 12 Pro Max's primary (wide-angle) sensor is big. Not unlike the phone it lives in. We're skeptical when a "Pro" feature only makes it into a larger, more expensive model, but there's a decent chance this sensor wouldn't fit in the cramped corner of the smaller iPhone 12 Pro without compromises. It dwarfs the iPhone 12's sensor. It's 47 percent larger but is the same 12MP, so each pixel is larger and captures more light.
- The Max has the winning battery out of all the iPhones 12, not just in power, but in technology. X-ray vision shows that the Max's battery pack isn't quite full to the brim, but it's darn close—and the high-tech shape allows it to turn the corner on capacity. The Max power source weighs in at 14.13Wh, tipping the scales against the 8.57Wh mini battery and the 10.78Wh 12 and 12 Pro. It's a slight step down from the 15.04Wh pack in the iPhone 11 Pro Max, and it definitely falls behind the Galaxy Note 20 and 20 Ultra (16.69Wh and 17.46Wh respectively).
- With the Pro Max's logic board extracted, we're tempted to say it might be even more compact than that of the iPhone 12 mini; but the mini's integrated SIM reader leaves it at a disadvantage. The 12 Pro Max had a detached, modular SIM reader, as in the 12 and 12 Pro—which is also a bit more repair-friendly.
- Repairability Score: 6 out of 10 (10 is easiest to repair). Screen and battery are reasonably accessible for replacement. Most components are modular and replaceable. Some uncommon screws complicate all repairs, but reusable fasteners are preferred over adhesives. Waterproofing helps reduce the frequency of some repairs while complicating others. The glass back makes drops even more dangerous and requires a full case replacement if it breaks. ⏻

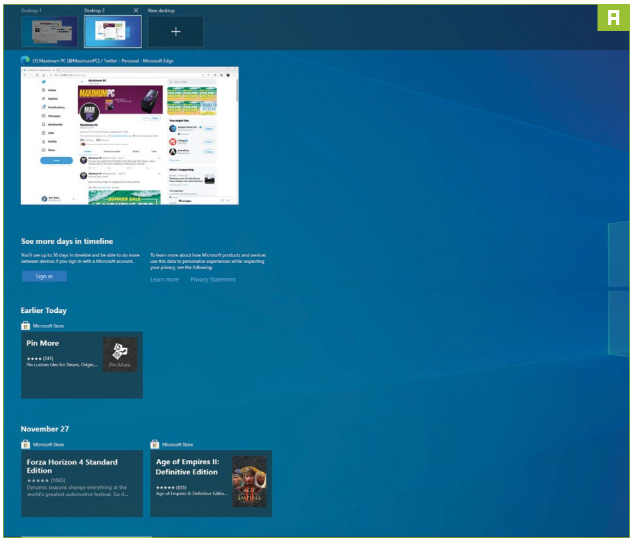
# Tidy Up With Virtual Desktops

### YOU'LL NEED THIS

**WINDOWS 10**
You can use Windows' own Task View option, or try a number of third-party apps.

**TIRED OF MANAGING AN UNRULY MESS** of a desktop, with tons of windows clogging up your view? There is a solution: Windows 10's virtual desktop feature. This lets you create a new instance of your current desktop setup, enabling you to divide your tasks into separate desktops, all walled off from each other. You might have a desktop with your work documents and apps open, for example, with another used for unwinding during your lunch break. That way, everything is neatly ordered and in control, without becoming overwhelming. You can't have different wallpapers or themes for your different desktops—instead, think of them as close copies of each other, with the main demarcation being the apps and windows you have open on each.

And instead of littering your desktop with shortcut icons for your favorite apps and games, you can pin them to your Start menu. Rather than using Windows 10's rather plain implementation, we are going to look at a few apps that give you much more control, helping to clean up your desktop and beautify your Start menu at the same time. All the methods outlined here are straightforward and easy to follow. Let's get started. **–ALEX BLAKE**



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Microsoft Store

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★★★★ (241)
Pin custom tiles for Steam, Origin,...

November 27

Microsoft Store

Forza Horizon 4 Standard Edition
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Microsoft Store

Age of Empires II: Definitive Edition
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Age of Empires II: Definitive Editio...

### 1 CREATE A VIRTUAL DESKTOP

There are several ways to create a new virtual desktop, either through Task View or by using a keyboard shortcut. The first method is to press the "Task View" button immediately to the right of the Windows 10 search box. If you can't see this button, press the Windows button (Win) and Tab. Both methods open the Task View, which displays all your open app windows. At the top of the screen you will see a button reading "+ New Desktop." Click it and a second desktop icon opens at the top of the screen; click that to switch to it.

» If you prefer a quicker way, simply press Ctrl-Win-D. This create a new virtual desktop and immediately switches to it.

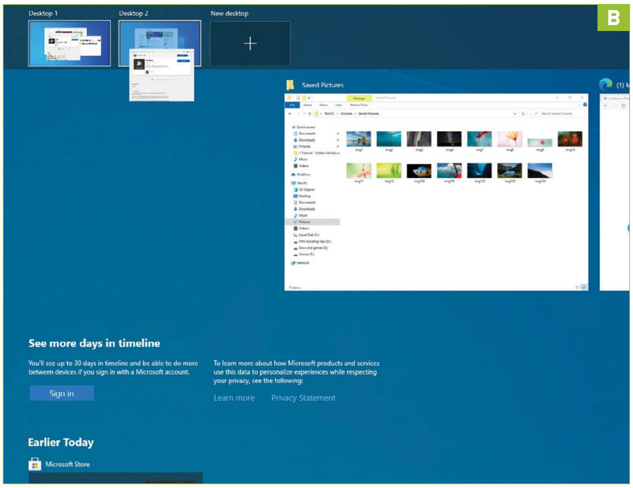
### 2 REMOVE UNWANTED DESKTOPS

Once you have finished with a virtual desktop, you can delete it to keep things in order. Press the "Task View" button or Win-Tab to open Task View. At the top of the window you will see "Desktop 1," "Desktop 2," and so on. Hover over the desktop you want to delete and an X appears above its top-right corner; click it to remove the virtual desktop. If you prefer to use keyboard shortcuts, however, simply press Ctrl-Win-F4 to delete the currently open virtual desktop. If you have windows open, these are moved to the next available desktop (they move right to left when looking at the Task View window).

### 3 NAVIGATE BETWEEN VIRTUAL DESKTOPS

The standard way to navigate between your virtual desktops is to use Task View. When you press Win-Tab, you see previews of your virtual desktops along the top of the screen. Each one shows the windows and apps open on each desktop. If you hover your mouse over one [**Image A**], the apps that are open on that desktop appear lined up on your screen, and you can use the mouse or arrow keys to move between them. Click an app and you are taken to that desktop with the app you clicked in the foreground.

» Keyboard shortcuts make it quick and easy to switch between all your different virtual desktops. Simply press Ctrl-Win-Right or Ctrl-Win-Left to move right and left along the list of virtual desktops you have open. If you are using a trackpad, you can use a four-



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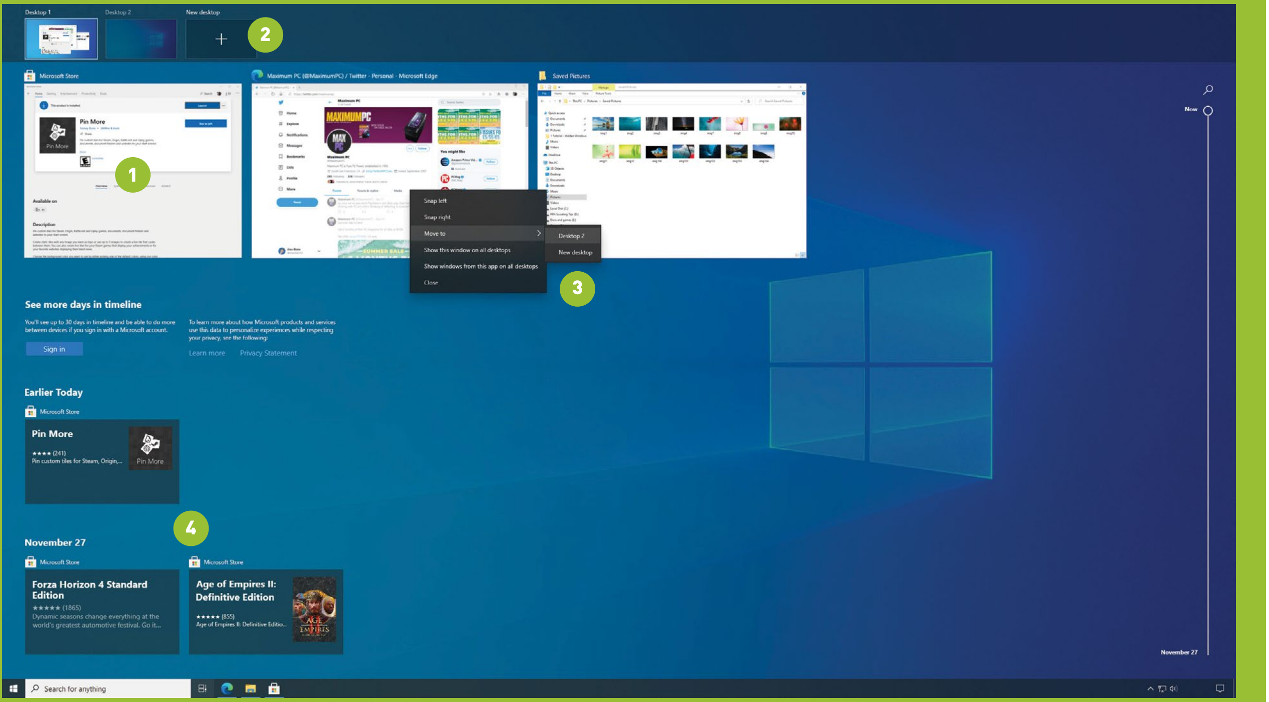
# THE TASK VIEW


Desktop 1
Desktop 2
New desktop
2
Microsoft Store
Pin More
1
Maximum PC (@MaximumPC) / Twitter - Personal - Microsoft Edge
Saved Pictures
Snap left
Snap right
Move to
Show this window on all desktops
Show windows from this app on all desktops
Close
Desktop 2
New desktop
3
Now
See more days in timeline
Sign in
Learn more
Privacy Statement
Earlier Today
Microsoft Store
Pin More
★★★★ (241)
Pin custom tiles for Steam, Origin,...
4
November 27
Microsoft Store
Forza Horizon 4 Standard Edition
★★★★★ (1865)
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Age of Empires II: Definitive Edition
★★★★★ (855)
Age of Empires II: Definitive Editio...
November 27
Search for anything

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**1. OPEN APPS**
All apps open on the current desktop are shown here. Hover over a different desktop and you instead see the apps that are open on that desktop.

**2. ACTIVE DESKTOPS**
Your current virtual desktops are shown along the top. You can close them or add new ones as you wish.

**3. RIGHT-CLICK OPTIONS**
Right-click an app and you can move it to a different desktop, snap it to a side of your screen, close it, and more.

**4. ACCOUNT ACTIVITY**
The Task View can also can be used to view your history and activity. If you are signed in with a Microsoft account on several devices, you can see their activity here, too.

finger swipe left or right instead to move through your desktops even more quickly.

» Note that when you switch to a new desktop, any apps that were running on your original desktop continue operating. That means if you are playing music on Desktop 1 and switch to Desktop 2 without pausing it, you can still hear your music even though your music app is not open on the new desktop.

## 4 CUSTOMIZE YOUR DESKTOPS

Now that we have mastered the basics, we can start going a bit deeper. On the Task View screen, right-click an app. You will see several options: "Snap left," "Snap right," "Move to," "Show this window on all desktops," "Show windows from this app on all desktops," and "Close."

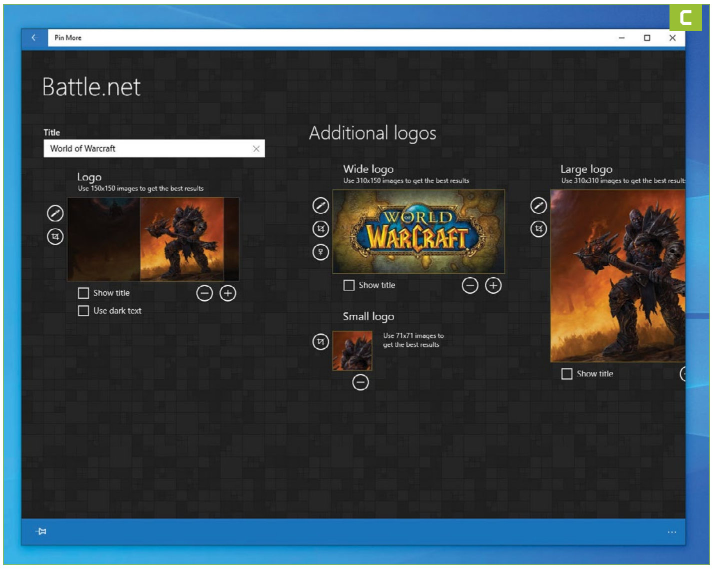
» The first two open the desktop with the selected app snapped to the left or right side of your display and your other apps shown on the other side, which is useful for multitasking. Hover over "Move to" and a submenu opens out, with options for moving the app to an existing virtual desktop or a new one. Another way to move apps between desktops is to simply drag and drop them [**Image B**]. You can drag an app from the preview of one desktop to another. If you drag it over the "New desktop" button and release, it creates a new virtual desktop and is moved there.

» "Show this window on all desktops," as the name suggests, duplicates the window to appear on all your virtual desktops. However, if you have more than one window open from the same app, it only duplicates the window that you have selected. To copy everything from that app, choose "Show windows from this app on all desktops" instead. Finally, you can close an app window by selecting the last option in the menu.

## 5 MULTITASKING SETTINGS

If you want more control over your virtual desktops, open the Settings app and click "System." In the left-hand sidebar, click "Multitasking," then head to the "Virtual desktops" section at the bottom. Here, you can choose whether the taskbar only displays apps that are open on the currently selected virtual desktop, or whether it shows apps that are open across all your desktops. You can also change whether the app switcher shortcut (Alt-Tab) shows apps from every desktop or just the one you are currently using.

» If you switch to an app that is open in another desktop—whether that is by clicking its taskbar icon or using the app switcher—you are immediately taken to the desktop that it is open on. However, if you have an app open on another desktop, Shift-clicking the app's icon in the taskbar doesn't open another instance of it on your current desktop. You can open the app from the Start menu or by searching for it, but it seems you can't open it across multiple desktops using the taskbar.


C
Pin More
Battle.net
Additional logos
Logo
Use 150x150 images to get the best results
Wide logo
Use 310x150 images to get the best results
Large logo
Use 310x310 images to get the best results
Small logo
Use 71x71 images to get the best results
☐ Show title
☐ Use dark text
☐ Show title
☐ Show title

Title: World of Warcraft

## 6

## GET PIN MORE

There are other ways to tidy up your desktop. One way is to pin your frequent apps and folders to the Start menu instead of covering your desktop in a sea of shortcut icons. To do so, we are going to use Pin More, an app that enables you to pin all sorts of things to your Start menu, including documents, folders, websites, and games from Steam, Origin, Battle.net, and Ubisoft Connect.

» Open the Microsoft Store app and search for “Pin More.” It costs $2.99. There are free alternatives, but none that cover as many bases as Pin More. Once you have downloaded and installed it, open the app, then choose what you want to pin.

## 7

## PIN A FOLDER

From the Pin More main menu, click “Folders.” Enter a title, click “Pick folder,” navigate to the folder you want to use, then click “Select Folder.” Click “+” under “Logo” to add an image to use as an icon for the folder; this is the icon that will show up on the Start menu tile. You can move the outlined square to include just the portion of the image you want. If the image is stretched or squashed, use the crop button to resize it. The “Logo” option is required, but you can add small, wide, and large logos, too, which will be used if you change the tile’s size on the Start menu.

» Once you have chosen an image, you can make a few adjustments should you wish. “Show title” and “Use dark text” are deselected by default. The first displays the folder title over the bottom-left corner of the icon, while the second switches the text’s color from white to black. To the left of the icon are buttons to crop it and select a color from the image; any color you pick is used as the background for the other tile sizes [**Image C**]. Finally, you can copy the image chosen for the wide tile for use on the required logo tile by clicking the third button to the left of the wide tile (it looks like a square with an arrow underneath it).

» When you are done, click “Pin to Start” in the bottom-left corner. This adds the tile to the Start menu, where it can be moved and resized as needed.

## 8

## PIN A GAME

While the process for pinning websites and documents is like that for folders, pinning games is a little different. If you have Origin, Battle.net, or Ubisoft Connect installed, Pin More automatically detects the games in your account and lists them in a grid of tiles. The same is true for Steam, except you must enter either your Steam ID or your profile name first, and ensure your profile is set to public.

» To pin a game, first select it from the grid. You will see a menu similar to that for pinning a folder, except the logo and wide logo fields are already populated with the game’s artwork (the small and large logos are filled with a color automatically drawn from the artwork).

» If you feel the artwork doesn’t match your taste or doesn’t look right (as is often the case with the square logo), click the minus button underneath it, and add a new image, following the same process as we did when pinning a folder. When you are finished, click the “Pin to Start” button and rearrange it if required.

## 9

## WHY USE TILEICONIFIER?

Pin More is very easy to use but is a little limited. For example, there is no option for pinning apps, so you have to stick with the default Windows 10 style, which may not be ideal (especially if you want to change the icon or remove the app’s name from the tile).

» In these cases, we recommend using TileIconifier, a free app that enables you to pin almost anything and customize its appearance [**Image D**]. To get started, download it from http://bitly.com/TileIconifier (the URL is case-sensitive).

## 10

## CHOOSE A NEW ICON

The first thing you will notice is that TileIconifier is a little more old-fashioned than Pin More. That’s OK, it’s still a piece of cake to use. After it has finished loading, a list of your installed apps appears on the left—scroll down until you find the one you want, or search for it in the “Filter” box. Click an app to select

## THIRD-PARTY ALTERNATIVES

As we touched on in the introduction, multiple desktops are not totally separate from each other, with your original instead working as a kind of template for subsequent additions. That means that if you set a new wallpaper on a new desktop, it is also applied to the original. Any icons you move on your desktop, or settings you change, are rolled out across all active desktops. You can’t rename your desktops, either.

If you want more control than Windows 10 offers you, there are third-party alternatives that are worth a try. Peach (http://peachapp.net), for example, enables you to rename desktops, or pin apps on top of other apps on every desktop, and adds a bunch of new keyboard shortcuts for managing virtual desktops.

Dexpot (http://dexpot.de) gives you much more control over the visual aspect of running multiple desktops, letting you give each one a different wallpaper and move icons wherever you like without other desktops being affected. It also has a ton of extra options, including customization rules, configurable hotkeys and mouse gestures, and more.

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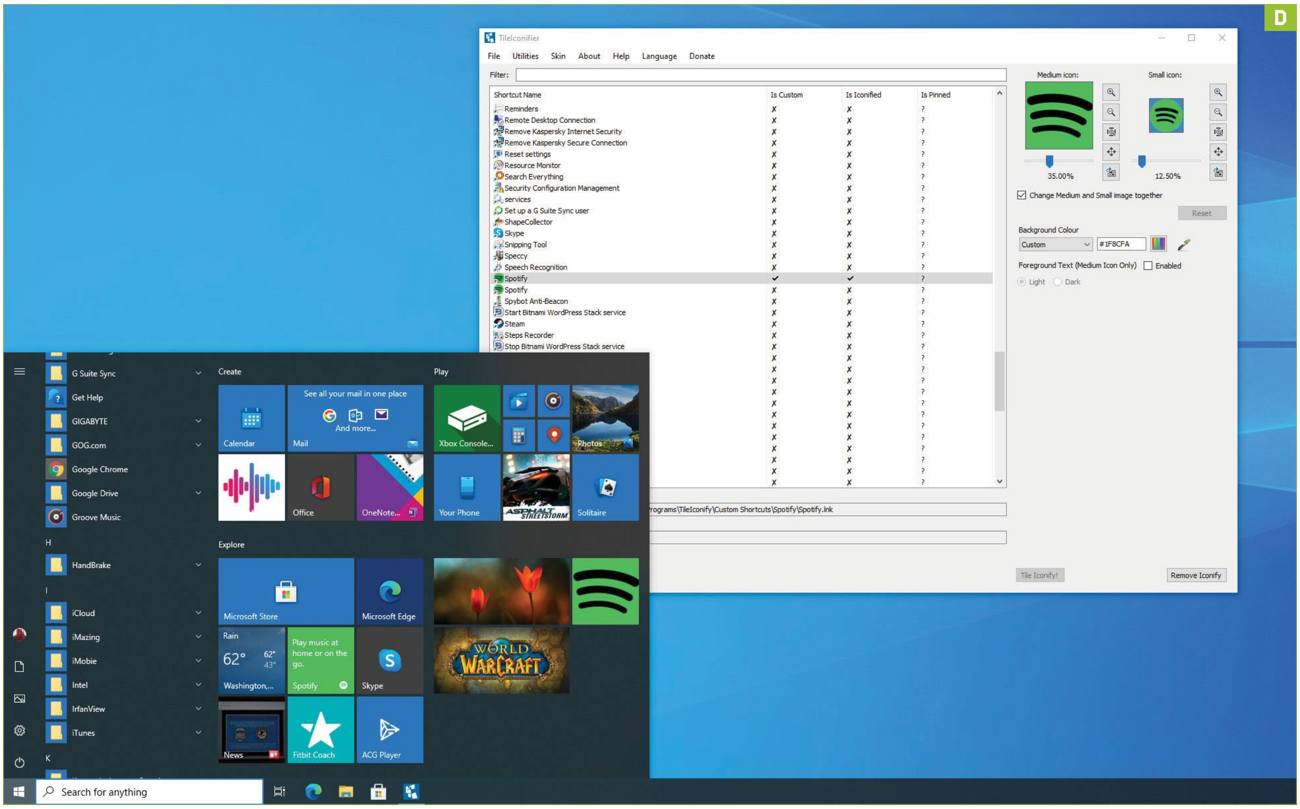
D
TileIconifier
File Utilities Skin About Help Language Donate
Filter:
Shortcut Name
Is Custom
Is Iconified
Is Pinned
Medium icon:
Small icon:
35.00%
12.50%
Change Medium and Small image together
Reset
Background Colour
Custom
#1F8CFA
Foreground Text (Medium Icon Only)
Enabled
Light
Dark
Tile Iconify!
Remove Iconify
Create
Play
Explore
Search for anything

it. Double-click either the "Medium Icon" or "Small Icon" box. A window opens showing every icon stored within the app's .exe file. You can choose one here or select one from elsewhere by clicking "Use custom image" and browsing to a file. You can use any image or icon file.

## 11 TWEAK ITS APPEARANCE

Once you've chosen an icon, there are several changes you can make. Directly under the icon is a slider that adjusts the zoom level for the image. You can also use the controls to the right, which include a button to align the image to an edge or the center of the frame. There is a checkbox to ensure changes applied to one icon size also apply to the other.

›› Below this is a drop-down menu for the background color. You can choose from several presets or use a custom color picker. This only has an effect if you use an image with transparent areas or if you zoom your icon out far enough that the background color shows. Finally, you can hide the app's name or change its color from light to dark.

## 12 PIN A FOLDER

Pinning a folder requires a slightly different process. Click "Utilities" in the top menu, then click "Custom Shortcut Manager." Click "Create New Shortcut" in the new window. You can select one of Windows 10's special folders (such as the Action Center or the Recycle Bin), or use a custom folder of your choice. If you select the latter option, click "Browse" to find the folder you want.

›› Click the icon in the bottom-left to change the shortcut's image and enter its display name in the "Shortcut" box. Choose whether you want the new shortcut to appear for every user on your PC or just you, then click "Generate Shortcut." After you have made your changes, click "Tile Iconify!" and let the app get to work.

## 13 PIN THE NEW SHORTCUT

Unlike Pin More, TileIconifier does not automatically pin the finished product. Instead, it is added to the TileIconify folder in your Start menu. Find the new shortcut there, right-click it, then click "Pin to Start," and reposition or resize it to your taste. ⏻

## TILEICONIFIER'S ADVANCED CONTROLS

TileIconifier has several useful features if you want to go deeper with your tile customization. One of the most useful is the batch tool. Click "Utilities" in the TileIconifier menu bar, then click "Batch Shortcut Operations." Put a check in the checkbox next to every shortcut you wish to amend, then choose what changes you want to apply. It is particularly useful if you want to theme your Start menu by adding a uniform background color to all your tiles, for instance, or if you want to add or remove the app name on each shortcut.

Elsewhere, you can find all your custom shortcuts by clicking "Utilities," then "Custom Shortcut Manager." From here, you can create a new shortcut, delete existing ones, and adjust the settings for previously created shortcuts. You can also see whether the shortcut affects just you or all users on your PC, and what type it is (Explorer folder, Microsoft Store app, and so on).

Some apps may refuse to be tiled properly. If that happens, select your desired app from the list, then click "Quick Build Custom Shortcut." This creates a second shortcut using the same parameters as the original, which you may be able to pin properly instead.

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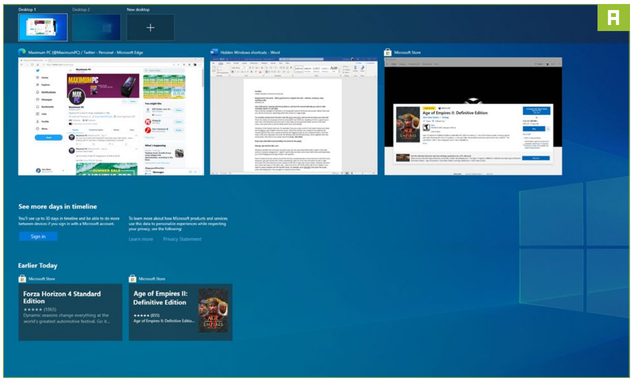
# Master Hidden Windows Shortcuts

YOU'LL NEED THIS

**WINDOWS 10**
And a keyboard for all the shortcuts!

**ONE OF THE KEY STRENGTHS** of Windows is its Smaug-like hoard of shortcuts and secrets. Master them and you will zip around your operating system like a hare on a sugar binge.

You probably already know the basic ones, such as Ctrl-C and Ctrl-V, so today we are going to look at some power user shortcuts. Speaking of which, a good one to start with is the Windows key (Win) and X. Press these and you get the hidden version of the Start menu, with quick links to various handy admin tools and settings. Windows is full of great shortcuts. For example, if you're using a work PC and need to leave your desk, hit Win-L to go straight to the lock screen. Want that sentence you copied to the clipboard 20 minutes ago but have since copied something else? Win-V brings up your clipboard history. Then there's the most important one: Win and the period key, which shows the emoji picker. That's true master-level knowledge. **–ALEX BLAKE**



## 1 MANAGE APP WINDOWS LIKE A PRO

Windows and Mac fans will never see eye to eye, but one area where Microsoft's system is the clear winner is window management—Apple's macOS doesn't even come close [**Image A**]. With a few swift keystrokes, you'll be flinging around app windows with aplomb.

›› Most of these shortcuts revolve around the Win key, located between Ctrl and Alt on the left of your keyboard. Let's get started with a little multitasking, shall we? Press Win and either the left or right arrow key; this moves the current window to the left or right side of your screen. Windows shows your other open apps on the other side—select one and it fills the other half of your display [**Image B**]. If you want to move a window into the top-left corner, for example, press Win-left, then press the up key while still holding Win. Press up again to maximize the window.

›› To minimize all windows except the current one, press Win-Home, or shake the app's title bar. Press Win-Home again to restore the windows. If you want to minimize all windows including the one you're using, use Win-M or Win-D. And if you just want to peek at your desktop, press Win and the comma key.

## 2 GETTING AROUND WINDOWS

Who needs a mouse? With a few keyboard shortcuts, you can access almost anything in Windows. For instance, press Win-T to move the focus to the taskbar, then use your arrow keys to select an app; Enter opens it, while Shift-Enter opens a new instance. Similarly, Win-B puts the focus on the notification area, while Win-A opens the Action Center. If you need to quickly adjust something in the Settings app, press Win-I (display settings have their own Win-U shortcut). Likewise, press Win-Pause (on full-size keyboards) to see your system information.

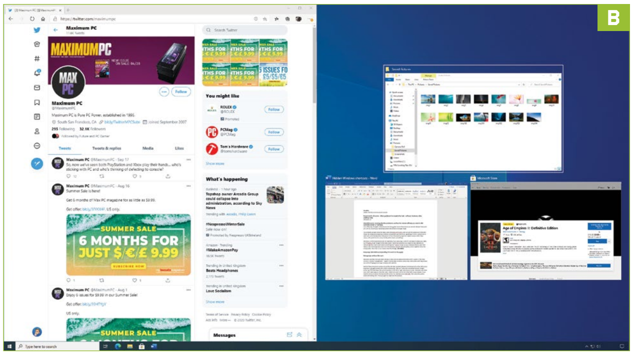
›› You may know that Alt-Tab switches apps, but Ctrl-Alt-Tab makes the switcher stay open when you release the keys, so it's easier to change apps. Go another level up by creating a new virtual desktop with Ctrl-Win-D. Use Ctrl-Win-left or right to switch virtual desktops, and Ctrl-Win-F4 to close the currently open one.

›› Finally, you can speed up your Start menu navigation by clicking a section header in the list of apps (for example, the letter A above all apps beginning with A). This then shows apps that begin with a letter of your choice, saving you from scrolling.

## 3 MASTER THE FILE EXPLORER

The built-in file browser in Windows has a few tricks up its sleeve. Some are simple but obscure: F2 enables you to rename the selected file, while F3 puts the focus in the File Explorer search box, letting you find a file in the currently open folder. To create a new folder, press Ctrl-Shift-N. We also like the Alt-Enter shortcut, which opens the Properties dialog box for the file you have highlighted.

›› Navigating around File Explorer is also made easier with some keyboard shortcuts. Pressing Alt and the left or right arrow key moves you back and forward through the folders you've browsed through. A similarly useful combo is Alt-Page Up and Alt-Page Down, each of which moves you up or down a level in your folder structure. ⏻



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# Machine of the Month: Amstrad CPC (1984)

**THE AMSTRAD CPC** may be unknown in the US, but this British machine was a darling of Europe and a key player in the 8-bit gaming world. A product of Lord Alan Sugar (Donald Trump's British counterpart on the UK *Apprentice*), this machine was designed to take the fight to the mighty Commodore 64 and British rivals such as the BBC Micro and ZX Spectrum.

With a production run lasting into the mid-'90s, there is an enormous amount of software for any retro gamers seeking undiscovered gems. However, the machine was never launched in the US, meaning emulation is the only real option for Americans wanting some Amstrad action.

So, come along as we explore the history of this overlooked machine, and provide instructions for emulating the Amstrad CPC in the easiest ways possible. –JOHN KNIGHT

### YOU'LL NEED THIS

**CAPRICE32**
Both 32 and 64-bit versions are available. Linux users who don't have a native package available in their repositories need a distro with Snap support enabled. https://bit.ly/39Ly6Du

## 1 A BRIEF HISTORY

When it came to the original CPC464, Sugar made some interesting design choices. Where other micros relied on separate televisions and tape decks, Amstrad's tactic was to simplify the system by integrating the cassette deck into the microcomputer itself. And fighting the established wisdom of television-based micros, Amstrad gambled on people wanting to use a stand-alone monitor instead of sharing the family TV.

» Microsoft's BASIC—the language of nearly all other micros—was seen as too expensive, so Sugar cut costs by commissioning his own BASIC interpreter.

» While rivals kept gaming at a distance from their company image, Amstrad actively embraced gaming, starting its own Amsoft label to bundle a selection of games with the machine.

## 2 THE GAMING EXPERIENCE

Sporting 64K of RAM and a Z80A CPU, the 464 is perhaps somewhere between a Commodore 64 and ZX Spectrum. Its General Instrument AY-3-8910 sound chip was something of an 8-bit micro standard, and although its sound was a lot more "bleep-bloop" than the immortal SID chip in its Commodore rival, it did at least have stereo. On the other hand, its Zilog CPU was faster than the Commodore, and the Amstrad didn't suffer from the Spectrum's ghastly color clash.

» Love it or hate it, the CPC's color palette is especially bright and was one of the standout features of the system, making Commodore 64 games look muted in comparison.

» Unfortunately, a shared CPU meant a lot of Amstrad games were simply ported from the Spectrum, often badly. A good release was similar to a Commodore 64 game, with brighter colors and the advantage of a faster CPU.

» Horizontal scrolling was the Achilles heel of Amstrads, where platformers tended to be flick-screen rather than use proper four-way scrolling. Nevertheless, there is plenty of classic gaming to be had. The '80s produced classics such as *Who Dares Wins 2, Tornado Low Level, Head Over Heels, Spindizzy,* and a solid port of *Arkanoid.* When the '90s arrived, coders were really getting to grips with the system, with more advanced games such as *Prehistorik II,* and a very respectable version of *Prince of Persia*, the only official port on an 8-bit platform.

## 3 HOW DID IT PLAY OUT?

Quite well, actually. Although overshadowed by the Spectrum and C64, it still managed to be the third biggest selling micro in the UK, with solid sales in Germany and Spain, and it was phenomenally successful in France, becoming the biggest selling micro there.

» The 464 was followed by models such as the CPC664 and CPC6128, which featured 128K of RAM, and rather weirdly, an internal 3-inch (not 3.5!) floppy drive.

» By the end of its life, the CPC had sold around three million units. Despite being discontinued in 1992, the last commercial title, *Megablasters,* was released in December 1994.

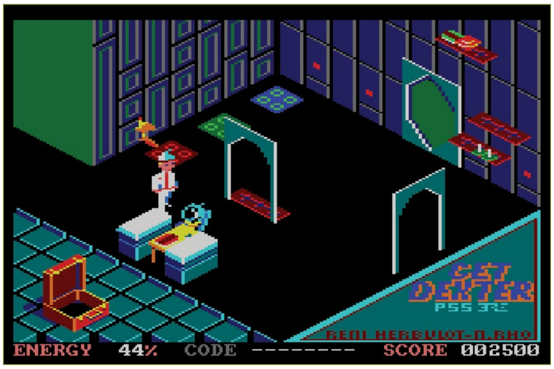
## 4 EMULATION

If all you want to do is play a few games, for compatibility and ease of use, just use RetroArch. It's available on all major platforms and well supported. At the time of writing, there were two Amstrad cores available: Caprice32 and CrocoDS. Grab both.

» The Caprice32 core generally gives the best results—it automatically loads files and generally gets out of the way. But it doesn't always pick the right file.

» When loading disks with CrocoDS, it provides a menu from which you can choose a file name and select by pressing X. However, you can't really use most of the keyboard with CrocoDS, as it uses lots of shortcut keys, and Amstrad games frequently use the keyboard. If a game doesn't work with one core, use the other.

» More bespoke, Retro Virtual Machine has a great interface but isn't stable enough yet, though it will be our



**» *Get Dexter* (1986) is a classic French title that used Amstrad hardware properly—as recommended by the Smith family, London.**

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Amstrad 64K Microcomputer (v1)
©1984 Amstrad Consumer Electronics plc and Locomotive Software Ltd.
BASIC 1.0
Ready
AMSTRAD

**›› The Amstrad's strikingly colorful buttons add to the visual effect Alan Sugar cynically dubbed "a mug's eyeful."**

first choice when the code is tightened. Windows users should also try WinAPE. But for now Caprice32—the program the RetroArch core is based on—is the best choice across platforms.

## 5 INSTALLATION

Head to the website, where links and instructions are provided for both Windows and Linux: https://github.com/ColinPitrat/caprice32. Windows users are given a choice of a 32 or 64-bit zip file. There is no self installer, so you need to extract the zip file and manually open the executable, cap32.exe.

›› Linux users are provided a Snap, or masochists can build it from source. Depending on your distribution, the Snap should either be available in your software store, or you can follow the instructions at https://snapcraft.io/caprice32.

## 6 USAGE

Once Caprice32 has started, you are presented with the Amstrad's BASIC prompt. To load a disk image, press F1 to open Caprice32's system menu, and click the "Load/Save" button, which opens a new window. Under "File type" leave it as "Drive A (.dsk)" and leave "Action:" as "Load." Search for your Amstrad disk images in the file browser below, select your file, and click "Load." Back in the main menu, click "Resume" to return to the BASIC prompt.

›› Once a disk is loaded in an Amstrad (whether in real life or emulated), browse the disk by typing:

```
cat
```

›› This lists the files in your disk image—look for anything with the extension .BAS or .BIN. If there is a .BAS file, try that first; if it doesn't work, try a .BIN file.

›› To start a program, using ARKANOID.BAS as an example, drop the .BAS extension and enter:

```
load"arkanoid
run
```

›› If you're running a game that requires multiple disks, you're prompted to change or turn over the disk mid-program. Press F1, open the "Load/Save" menu, and choose the next disk image. Back in the main menu, click "Resume," and you should be OK.

›› On the off chance you find a tape file, press F1 and open the "Load/Save" menu as before. This time under "File type," choose "Tape," and click "Resume."

›› Back in the BASIC prompt, enter:

```
|tape
run"
```

›› The prompt now tells you "Press PLAY then any key:." Press F4 to engage the virtual tape mechanism, followed by any regular non-function key.

›› Wait a while and you're greeted by a loading screen with the same screaming noises old modems emitted. Go play a game of baseball, and when you return, your game may have finished loading. Use disks if possible. ⏻

## FINDING SOFTWARE

As usual, http://archive.org has lots to offer; the "Amstrad CPC Game Collection By Ghostware" has a huge selection.

For an Amstrad-specific website, http://cpcrulez.fr is in a mixture of French and English, but you should be able to guess your way around. There are loads of ROMs—which we can't advocate—including both disk and tape dumps, but they also include freeware, public domain software, and demos, so we can at least recommend those.

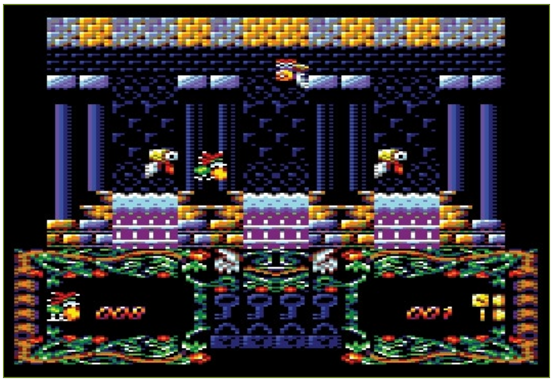
For new games, www.retroworks.es has a couple of free titles, including *Teodoro no Sabe Volar* (2012), a great Spanish platformer thick with atmosphere and difficulty.

But there's nothing quite like the CPCRetroDev community, which keeps the Amstrad alive with a steady stream of new games, year after year. We particularly like *Baba's Palace* (2017), a fiendishly clever puzzle game with a fantastic theme tune, which combines *Sokoban*-style gameplay with platformer elements.

## SPECIFICATIONS

Amstrad CPC (1984)

| | |
|---|---|
| CPU: | Zilog Z80A @ 4MHz |
| RAM: | 64KB |
| Launch price: | £199 monochrome, £299 color |
| Graphics: | 16 colors @ 160x200, 4 colors @ 320x200, 2 colors @ 640x200 |
| Sound: | General Instrument AY-3-8910 3 PSG |
| Storage: | Cassette and 3-inch floppy |
| OS: | AMSDOS and Locomotive BASIC |
| Released: | April 1984 |
| Production: | 1984–1992 |
| Worldwide sales: | 3 million |



**›› 2012's *Teodoro no Sabe Volar* beautifully encapsulates the visually detailed but highly difficult platformers that typify the Spanish Amstrad scene.**

© WIKIPEDIA, RETROWORKS

# BUILD IT

**NIELS BROEKHUIJSEN**, WRITER FOR TOM'S HARDWARE

# Mirror Maze PC

Get lost in a silent labyrinth of mirrors, nickel, and chrome

LENGTH OF TIME: **16–24 HOURS DEPENDENT ON SKILL** | LEVEL OF DIFFICULTY: **ADVANCED**

## THE CONCEPT

**THERE'S A** couple of approaches you can take to building a PC. By far the most common is a rather pragmatic one, where you build a machine that's solely meant as a means to a specific end (say, for gaming, or some other task, or within a set budget), keeping looks in the back of your mind, but mostly as a side concern. However, with this build we decided to take a completely different approach.

This month, we're not building a PC that's meant to squeeze as much power as possible out of each dollar spent, but rather one that tries to offer the most refined experience—not just beautiful looks or record-breaking performance. Naturally, when tackling a build like this, custom liquid cooling is a must, as this will help keep the components cool and quiet, and obviously gives us that stunning aesthetic edge that we'd be unable to achieve with standard components.

That said, the whole idea for this build was sparked when Lian Li announced its PC-011 Dynamic in a Special Edition Space Gray variant. We knew this chassis could be the start of something great, and thus was born what we're calling the Mirror Maze build, a system with tons of reflective, shiny components designed to pump out frames and churn through productivity tasks, but be quiet enough that you'd barely notice its presence, even when running at peak performance.

GEFORCE RTX

## THE PARTS

**THE DECISION** to use the PC-011 Dynamic was an easy one to make. This chassis is among the most popular water-cooling cases out there, and it brings with it a robust platform of third-party hardware that you can pack into it as well. However, the standard model is common and a little plain, so we're spicing it up with this special Space Gray edition, a chassis built in collaboration with the PCMR community. It comes with mirrored tempered glass panels that, while making it a major pain to photograph, also make it perfect for the mirror maze theme we're going for.

On top of that, we've included an eight-core Ryzen 7 3700X, an Asus Crosshair VIII Formula motherboard, 32GB of G.Skill's Trident Z Royal memory @ 3,600MHz, an EVGA Nvidia GeForce RTX 2080 Super, a 1TB Samsung 970 Evo Plus M.2 SSD, an 850W Be Quiet! Straight Power 11 80+ Platinum PSU, custom cables from CableMod, and a ton of liquid-cooling componentry from EKWB, including a full-sized distribution plate, complete with pump and reservoir support, specifically designed for the PC-011 Dynamic. All of that is chilled by no fewer than nine Noctua NF-A12x25 fans, in that classic beige and brown color scheme (more on that later).

We originally built this system back in August 2020. Parts were still readily available, but since then, everything—regardless of whether it's a brand-new AMD chip or the last-generation graphics card—has increased in price, in some cases by a factor of two. We've also tweaked and changed the build quite a lot since we originally built it, so you might want to check out the final page, where we go into detail about what exactly we've swapped out since first putting this monster together.

### INGREDIENTS

| PART | | RETAIL PRICE | STREET PRICE 12/2020 |
|---|---|---|---|
| CPU | AMD Ryzen 7 3700X | $300 | $330 |
| GPU | EVGA GeForce RTX 2080 Super Gaming Black | $741 | $1,400 |
| RAM | 32GB (4x 8GB) G.Skill Trident Z Royal @ 3,600 CL16 | $168 | $170 |
| Motherboard | Asus ROG Crosshair VIII Formula | $600 | $800 |
| Primary Storage | 1TB Samsung 970 Evo Plus M.2 PCIe 3.0 SSD | $190 | $162 |
| Fans | 9x Noctua A12x25 PWM 120mm | $404 | $404 |
| Fan Lighting Rings | 6x 120mm Phanteks Halo Lux Light Rings—Gray | $120 | $140 |
| Liquid Cooling | Various EKWB | $885 | $885 |
| Coolant | EK-CryoFuel Clear (Concentrate 100ml) | $10 | $10 |
| Distribution Plate | EK-Quantum Reflection PC-011 D5 PWM D-RGB—Plexi | $350 | $350 |
| Cables | CableMod's ModMesh Custom Pro Cables with Carbon Colored Sleeving + Combs | $216 | $216 |
| PSU | Be Quiet! Straight Power 11 850W 80+ Platinum | $195 | $437 |
| Case | Lian Li PC-011 Dynamic, Space Gray Special Edition | $600 | $1,200 |
| Total | | $4,779 | $6,504 |

## 1

## SIDE RADIATOR INSTALL

**NORMALLY,** aside from stripping down the case and ensuring everything works beforehand, you'd chuck the motherboard in straight away, and get the hardware connected. But because the top radiator can only go in once the distribution panel is installed, and the side radiator only fits if the distro panel isn't installed, we're starting there. A 360mm radiator doesn't neatly fit in the bottom of the chassis without modification, but much like leaving empty RAM slots, we don't like the "incomplete" look that would result from a 240mm being situated there in this chassis. We could install three 120mm fans there instead, to add extra air intake, but we'd lose out on a significant chunk of surface area gained from that 360mm rad, and although our GPU and CPU aren't super-hot contenders, every little helps.

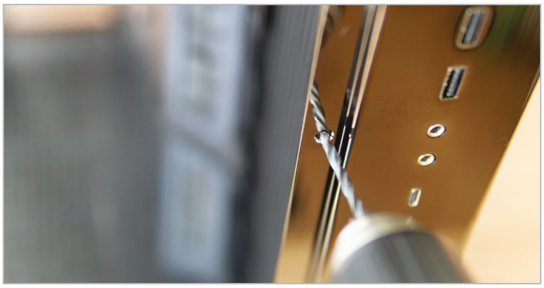
## 2

## PORTLY DECISIONS

**WE'D PREFER** the ports at the bottom, but that wasn't going to work. With a bit of a squeeze, the EKWB 360mm SE radiator fits in fine if you keep the ports at the top. This is because once we've installed the distribution plate, the ports will make contact with the integrated pump, and we wouldn't be able to get our tubing runs installed. We then installed the Noctua fans with their included radiator gaskets, making sure to orient them to draw cool air into the case. We should end up with six fans drawing cool air in, and three exhausting hot air out of the top, leading to a positive pressure system, which should reduce dust.

## 3 DIZZY PLATE DRILLING

**EKWB'S QUANTUM REFLECTION** distribution plate is an impressive bit of kit. It's a huge reservoir, with drain and fill ports included as standard, it has an integrated D5 PWM pump hidden inside, and it comes with RGB lighting as well. The only downside? It requires some serious assembly and case modifications to get it installed correctly. So, let's begin. First up, we have to drill some holes in the chassis where the included screws need to go through to secure the distro panel to the case. We used a metal bit, and that did the job nicely. We did immediately reach for the vacuum, just to ensure that we didn't leave any of the metal filings inside the case, and give them the opportunity to get into places where they don't belong. Let us assure you, stripping down a liquid-cooled loop because your GPU's shorted out thanks to one of these pesky little shavings getting inside the PCB isn't exactly what we'd call fun.



## 4 RADIATOR PREAMBLE

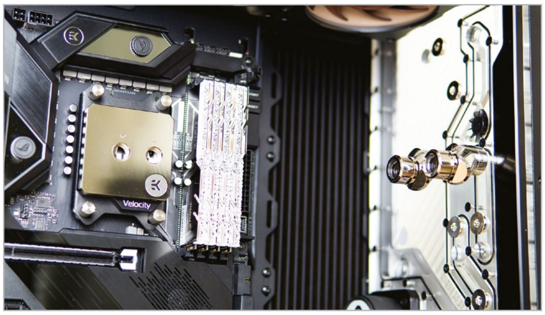
**ONCE THE HOLES** are drilled, it's simply a case of sliding the distribution panel into position and securing it in place. This thing fits in perfectly—no lumps, no bumps, just inch-perfect perfection. That said, at this stage we could sense some forthcoming issues ahead of us, so we decided it might be best to install two 90-degree angled adapter fittings on the side radiator early on, just so we could give ourselves a bit of flexibility when it came to those tubing runs later on in the build. The top radiator, once in, would make that particularly difficult to achieve. Or at least, it would be more difficult than doing it now, and we knew these two fittings would be going here anyway.

## 7 IN SHE GOES

**AS MUCH** as it tends to be easier to add things to the motherboard before installing it in the system, it does lead to one issue: The board can become ridiculously heavy. So, make sure your cat is nowhere to be found before hefting the whole setup into place. After checking for our feline companion in all of its usual hiding spots, we carefully placed the board and its components into position, and secured it down. Finally, the system was beginning to look like a build. We actually recommend that you leave a lot of the protective film on the motherboard until after you've completed the installation procedure—this way, if you do accidentally clip it with a screwdriver, you're less likely to scratch any of the surfaces.

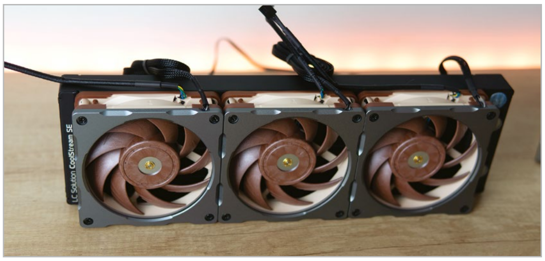
## 8 MOBO MISALIGNMENT

**WITH THE MOTHERBOARD** in place, we noticed another issue: The CPU block's water ports sat about half an inch lower than the ports on the distribution panel. Fortunately, we had some extra 45-degree fittings, so we grabbed four of those, along with one 14mm extender. This allowed us to get the ports at the correct height for the CPU block, making sure that the tubes would only need a single 90-degree bend later on. Port alignment is one of those frustrating things that you can't guarantee when it comes to liquid-cooled PCs, even when using components from the same company. It mostly comes down to your choice in GPU and motherboard. Because standards vary, to allow AIB partners to place sockets, GPUs, and memory in different locations, it means ports won't necessarily line up perfectly. Some manufacturers, such as Barrow, make off-set fittings now as well.



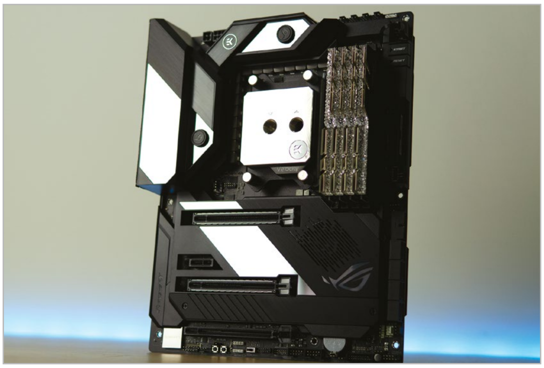
## 5 OF BEIGE AND LIGHTS

**WITH THE DISTRIBUTION** plate in, and the side radiator prepared, we moved on to prepping the top-most radiator. We started by installing the fans on it, along with the Phanteks Halo light rings. The long screws that came with the radiator were… too short. But Phanteks knew this was going to happen, which is why the Halos come with slightly longer screws, which were perfect for reaching the radiator and pinning the Noctua NF-A12x25 fans in position. Despite its water-cooling pedigree, the Lian Li PC011 Dynamic doesn't come with a top-mounted radiator bracket because, due to its versatility, you can also use it with air-cooling solutions, and if you had a bracket up there, it might ruin the overall aesthetics of the build, unless it was completely removable. So, we literally hoisted the radiator up into position, then secured it into the mounting holes at the top of the chassis using the included screws. After that, all the cables were tucked away to the rear to deal with later.



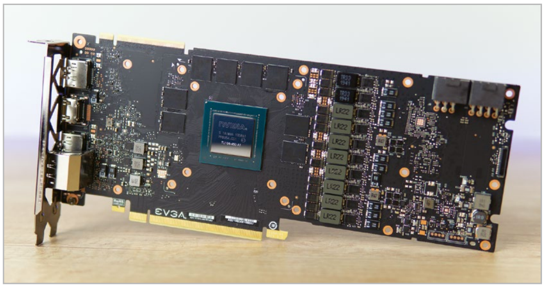
## 6 MOBO PREP

**TO MAKE** things easier, we added the 3700X, Samsung 970 Evo Plus M.2 SSD, G.Skill Trident Z Royal memory, CPU, and EKWB EK-Velocity CPU block before installing the motherboard. Adding the EKWB Quantum Velocity waterblock was a breeze. We removed the stock AMD mounting bracket, including its backplate, then installed the EKWB backplate with its rubber gasket at the rear. Four thumbscrews were placed at the front end, a dab of Thermal Grizzly paste was applied to the CPU, the block dropped on, and secured with more thumbscrews. However, our cat decided to pick the moment we were lowering the CPU block into place to jump up on the desk, causing us to drop it, denting the heat spreader. Fingers crossed it won't affect our thermals.



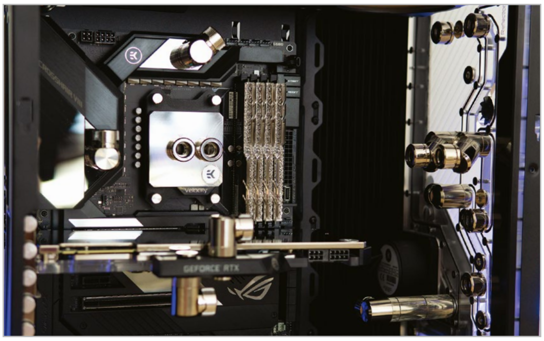
## 9 WHO'S THAT GRAPHICS CARD?

**INSTALLING THE WATERBLOCK** on the graphics card was less precarious than you might think. As long as you're patient with your tweezers while placing the thermal pads, and you're careful with each step of the disassembly, cleaning, and re-assembly with the waterblock on, it's not that scary. If you're disassembling another card, such as a Founders Edition from Nvidia, the company uses 4mm hex-socket screws, which allow screws to be installed into them as well. So, it's worth getting a custom 4mm hex-socket screwdriver to remove those. You can use needle-nose pliers, but it's very nerve-wracking and very easy to go wrong. About an hour and a half after starting, the EVGA RTX 2080 Super Gaming Black was converted into a shiny, thin, water-cooled GPU. We routed the D-RGB cable that leads to the lit-up "GeForce RTX" on the side terminal under the acrylic part of the block that doesn't cool. If you look very carefully, you can spot its connector.



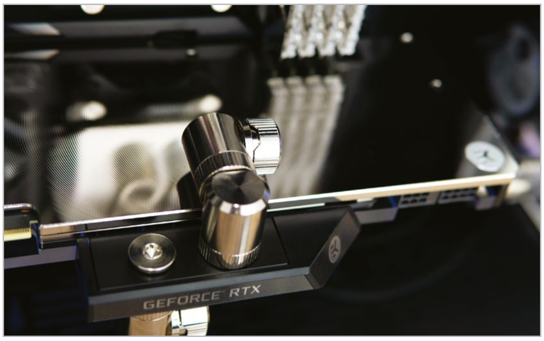
## 10 GOING LOOPY

**WE'RE ALMOST READY** to begin our tubing runs, but because some of the parts didn't fit quite as we'd planned, we needed to spend some time thinking about our future steps. This build has taught us that no matter how much you plan ahead, you're still going to run into issues, and you'll have to adapt. On EKWB's advice, we got more fittings than we thought we needed, and thank goodness we did. The adjustment for the CPU's ports already ate up four 45-degree angled fittings, and incorporating our VRM block used up another two 90-degree fittings and a 45-degree fitting on the radiator at the top—not counting the 14mm extenders to line the ports up nicely. The GPU also didn't line up well with the distro plate, despite being a reference card, so we used two more 45-degree fittings, along with two 90-degree fittings to align them.



## 11 OF PORTS AND EXTENSIONS

**TO REACH** the side radiator's ports at the top, we had to use the lower ports on the distribution panel. There is one port that's the outlet from the pump, which you naturally have to use. We chucked two 28mm extenders on this one, along with a 90-degree angled fitting, which lined it up precisely with the angled fitting we'd placed on the side radiator earlier, albeit with a long tubing run with one 90-degree bend. We placed the return line on the distribution panel at the top of a channel that would lead to the inlet of the GPU block, relying on another long tubing run with a 90-degree bend. All in all, while it was certainly complicated, we'd call this stage a big success: With enough fittings, everything lined up so that each tubing run would require only one 90-degree or 45-degree bend, which is key to a successful hard-tube build if you're a beginner.



## 12 TUBING FOR DAYS

**IT MIGHT COME** as a surprise, but bending the tubing and fitting it into place was much easier than we expected. The GPU's tubes were the easiest, requiring no bends at all, and the remaining tubes all required a maximum of one bend. These bends were also exactly 45 degrees or 90 degrees, meaning we could use the EK-Modulus tool to get them exactly right. So, we wet the silicon noodle insert, put it in the tubes, and warmed them up using a heat gun. Once they started giving way, we gave them a little extra time to soften up, careful to keep rotating them as we went along. For the side radiator, we bent the tubes too soon, which lead to some light kinking, but those corners aren't visible anyway—so they were good to learn on. Once bent, we simply cut the ends off the tubes where needed, deburred and sanded them down so they wouldn't damage the o-rings, wet them with some soapy water, and test-fitted them. In the end, it took a full day to get all the bits of tubing right, but we didn't ruin a single piece—it was easy enough, though it did require lots of patience.

# CONCLUSION

**NOW THAT** the system is up and running, we have a confession to make: This is the first time this writer has successfully built a custom loop with hard tubing. I attempted it before in 2015, when I did my first ever custom loop, but due to a lack of experience planning the bends, I ended up having to resort to soft tubing.

The Mirror Maze build, on the other hand, actually went quite well. The PC-O11 Dynamic is obviously an excellent foundation for a liquid build, and EKWB's Quantum-Reflection distribution plate, paired with enough fittings, ensured we wouldn't need more than one bend per tube. Sure, we ran into a few unforeseen hiccups during the build process, but these were easily sorted out. Even incorporating the Asus Crosshair VIII Formula's VRM block into the loop went without a hitch.

### FAN CURVES, OVERCLOCKING, AND HEAT

Not everything went smoothly, though. Remember, I dropped the CPU block on the Ryzen 3700X's heat spreader during installation. And, as predicted, the tiny bump didn't do thermals any favors. We didn't need to run the chip at stock settings, but enabling AMD's PBO (Precision Boost Overdrive) was the most we were comfortable with. With this, a Prime95 Smallest FFT's load translated to a CPU temperature of 84.5 C, and the CPU boosted to 4,002MHz on all cores. That's warmer than the CPU should run at under water, but it's within norms, and no cause for concern. As long as you get a CPU that's amenable to high clocks, and you don't drop any of the key components, you should see better results here.

Next, we overclocked the EVGA RTX 2080 Super Gaming Black. Using MSI Afterburner, we maxed out the card's power limits (116 percent), and offset the core clock by +150MHz and the memory by +1,000MHz. The GPU boosted to a stunning 2,100MHz under load, and under extended tests the temperatures didn't exceed 49 C in a 25 C room. We were able to push the chip a little further to boost to 2,115MHz, and although it ran stable and temperatures were still in check, we saw some minor artifacting, so backed off and kept it at the 150MHz offset.

For cooling, we quickly discovered a mistake in our loop: It lacked a sensor for coolant temperature. We were able to fix the pump speed at 35 percent, as this made it barely audible, and higher flow doesn't help temperatures anyway. However, the fan speeds were driven by the CPU's temperature, which isn't helpful when the GPU is able to dump 250W (or more) of heat into the loop, but the loop isn't instructed to dissipate this heat. This led the fans to ramp up far too quickly when the CPU briefly spiked in temperature. With some testing, we found that running the Noctua NF-A12x25 fans at 40–50 percent duty was more than enough to keep the system well cooled, with a solid safety margin, while remaining incredibly quiet. For reference, the coil whine produced by the graphics card isn't loud, but it was audibly louder than the system's cooling loop.

A future upgrade would therefor be to add a coolant temperature sensor to the loop as well, so that you would be able to set a fan curve based on this reading, and then push the system to run even more quietly. This would remove the noise spikes from that ramp up and only cool the fluid when it actually gets warm due to extended loads.

Nevertheless, we slapped on all the panels and dust filters, and ran our usual 15 runs of *Metro Exodus* to simulate half an hour of gaming. This resulted in an

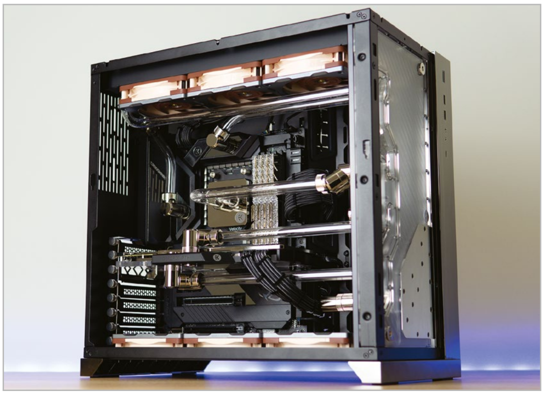
## 13 PRESSURE TESTING

**THE GENIUS/CRAZY PERSON** in us thought it would be a good idea to pressure-test while we installed the last fans and took care of cable management on the other side, but we couldn't have been more wrong. It turns out, the pressure tester works really well, but it's an extremely finicky device. The needle moves at the slightest bump, which led us to believe our loop was leaky—it wasn't. The trick to the pressure tester is to pump up the loop, close the valve, remove the pump, tap the pressure tester a few times to make the needle drop as much as it will by external force, and note where it is on the dial. Then leave the room. Do not touch the system. Don't even breathe near it. We checked on it periodically, and once it hadn't dropped after two hours under pressure, we were confident the loop was good. So, we unplugged all the cables on the PSU but the pump, jumped the ATX connector for the motherboard, and in the fluid went.

0.5
0.25
0.75
bar
0
1

## 14 ALL'S WELL THAT ENDS WELL

**AND THERE YOU HAVE IT,** our completed liquid-cooled Mirror Maze PC. Complete with controversial beige fans, an abundance of RGB lighting, clear coolant, and a distribution plate to die for. We're seriously happy with the end result, and despite the frustrations that arose from some of the conflicting parts and misalignments with the ports, all in all it looks like a really kick-ass machine, and sits proud and true on our desk. However, this isn't the end for this build, and since building it back in August prior to the launch of AMD and Nvidia's new product lines, we've made some significant changes to the hardware and even the coolant. But more on that on page 71. For now, let's take a look at some of the smaller details below....



average CPU temperature of 63.2 C, with an average GPU temperature of 46 C. Those are good figures if you consider that both are overclocked. We also pulled out the decibel meter and recorded a figure no louder than 38.8dBA. If you're familiar with case acoustics, you'll know that's extremely quiet.

### GAMING PERFORMANCE

Performance in gaming is also good. That's no surprise, of course, given that this system packs a pretty powerful GPU, not to mention the fact that the Mirror Maze build is both liquid cooled and overclocked.

Performance in *Shadow of the Tomb Raider* and *Metro Exodus* appears to scale the way it should, although in *Red Dead Redemption 2* and especially *GTA 5* we saw performance increases that cannot be explained. Trust us, we set all the graphic setting sliders to the highest level possible in order to get performance to go down, closer to other comparable systems, but the Mirror Maze has an inexplicable, very significant lead in these titles. We honestly don't know why—liquid cooling and overclocking help, of course, as do game updates, but not normally that much.

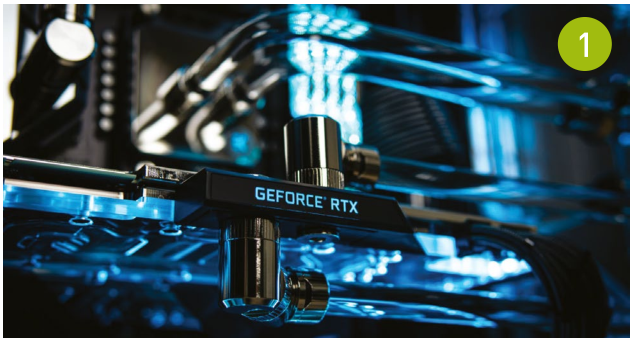
### BENCHMARKS

| | ZERO-POINT | |
|---|---|---|
| **Shadow of the Tomb Raider @ 1080p (avg fps)** | 92 | 96 (4%) |
| **Metro Exodus @ 1080p (avg fps)** | 63 | 73 (16%) |
| **Grand Theft Auto V @ 1080p (avg fps)** | 85 | 170 (100%) |
| **Red Dead Redemption 2 @ 1080p (avg fps)** | 63 | 77 (22%) |
| **Shadow of the Tomb Raider @ 4K (avg fps)** | 30 | 36 (20%) |
| **Metro Exodus @ 4K (avg fps)** | 38 | 44 (16%) |
| **Grand Theft Auto V @ 4K (avg fps)** | 80 | 110 (38%) |
| **Red Dead Redemption 2 @ 4K (avg fps)** | 23 | 43 (87%) |

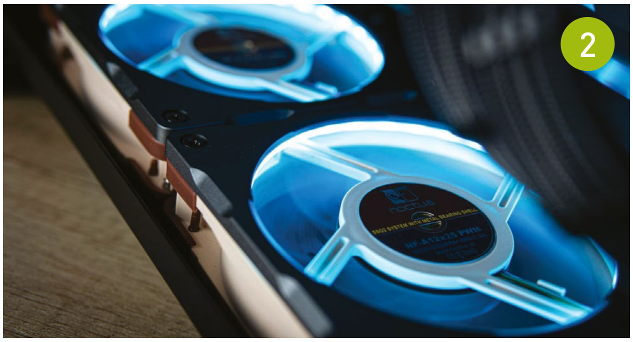
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an AMD Ryzen 9 3900X, Zotac GeForce RTX 2080 AMP Extreme, Asus ROG Strix B450-I Gaming motherboard, 16GB HyperX Fury RGB DDR4, and a Patriot Viper VPR100 2TB M.2 PCIe SSD. Games were tested at Max settings with RTX enabled where possible, and average FPS recorded.

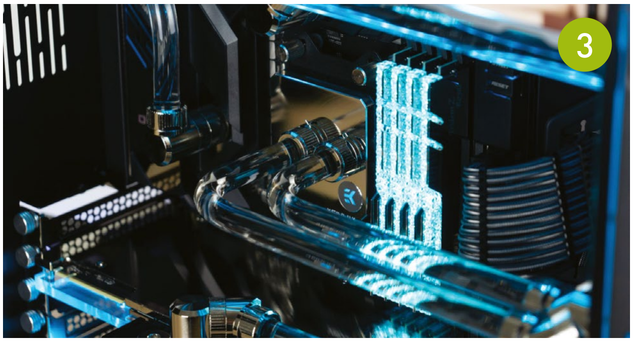
## OUT OF THE BLUE



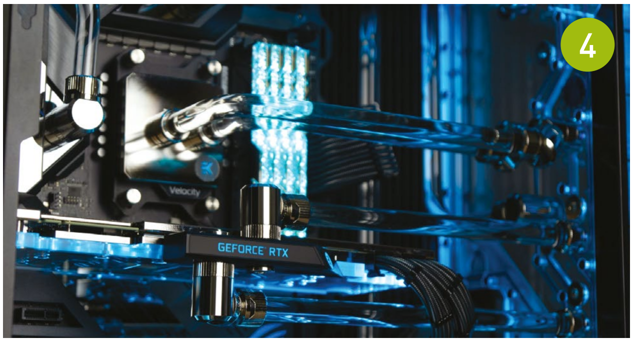
① The nickel fittings, clear coolant, and white lighting really make this build shine.



② We had our doubts about the Phanteks Halo Lux lighting rings, but they're darn cool.



③ G.Skill's Trident Z Royals aren't to everyone's taste, but the crystals diffuse light really well.



④ Having the distribution plate/reservoir in the front of the case makes building a loop a heck of a lot easier.

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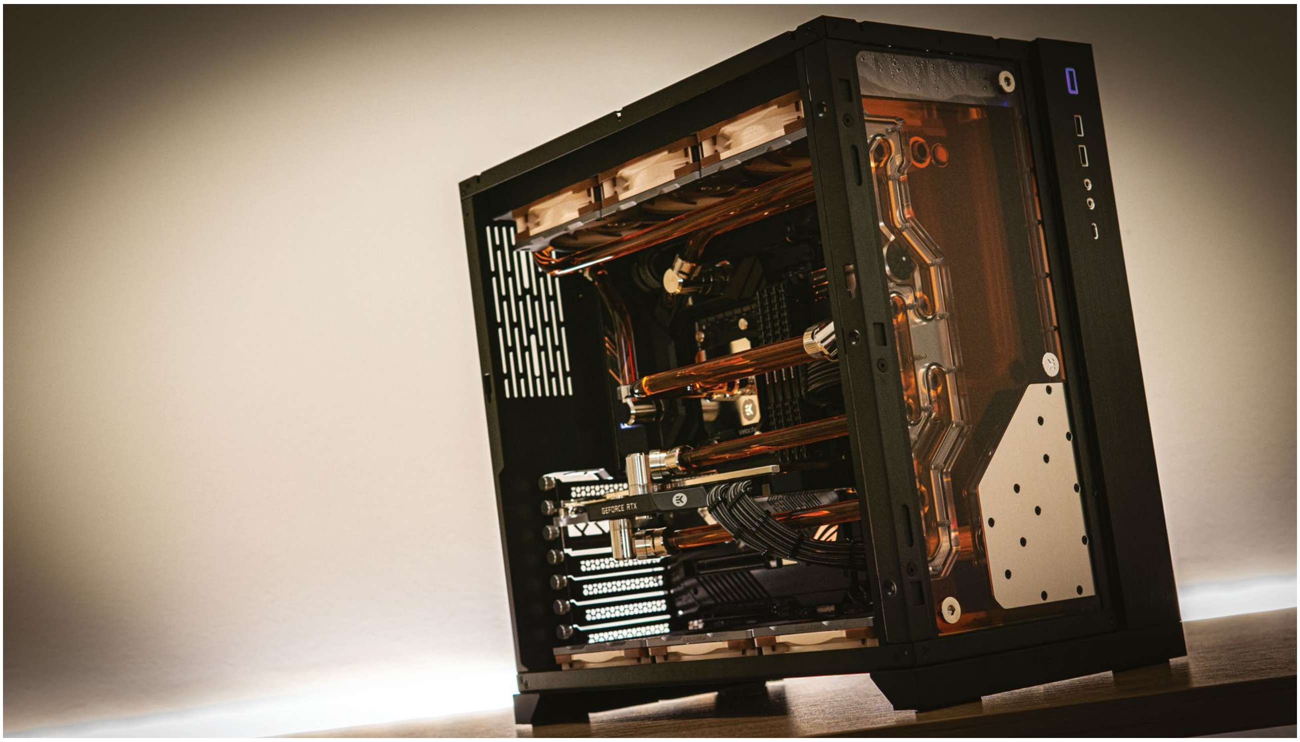
# NIPS AND TUCKS



**SINCE FIRST BUILDING** the Mirror Maze PC in August, we've changed the build considerably. In hindsight, we didn't like the ocean of RGB that was needed to see through the mirrored panels, so we ditched the PCMR version of the Lian Li PC-011 Dynamic and rebuilt the entire system in the standard black case with the regular glass panels.

We also swapped the CPU for a fresh AMD Ryzen 9 3900X, as thermals weren't great on the 3700X that we dented when first building the system. We also swapped the shiny G.Skill Trident Z Royal memory for plain, RGB-less Corsair Vengeance DIMMs, redid some tubing we weren't quite happy with, and installed a $10 fluid temperature sensor.

Then, when all was tested, we grabbed EKWB's fluid dye kit with the three base colors (yellow, blue, and red) and started dropping it into the fill port to get a coppery color that would complement the Noctua spinners. We know many folks don't like the brown-and-beige theme of these fans, but we personally love their Zen vibes, and felt that a copper-colored fluid would be the best accent for this system; no more playing it safe with neutral colors.

All this dye, beige, copper, and brownness ruined any attempt at using the RGB, so we turned off the distribution plate's lighting, plus that of the GPU and the Phanteks Halos on the fans, leaving only the motherboard's accent lighting and EK logo on the CPU block lit. Color: Amber. We still need to remove the Halos on the fans as we have no intention of using them, but that requires draining the loop to remove the top radiator so we can get to their screws—a job for later this year.

Hilariously, our changes also resulted in a more efficient system—all that RGB lighting was using up a staggering 25-30W or so.

## TIPS AND TRICKS

If you were to ask us what tips we could give you when doing your first hard-tubing build, we would tell you to ensure you need no more than one bend per tube, get plenty of angled fittings, use a pressure tester—and, no, a distribution plate isn't cheating (but it does make your life so much easier). Other than that, there's no more to it than customizing the parts to your liking, and taking lots and lots of time to do the build right. Because doing it wrong can be an expensive mistake.

The Mirror Maze build ended up roughly as we had expected it would. In terms of looks, the system means business by day with all the RGB lighting off. But at night, when it's time to play, it can put on quite a show—either customized to your liking or going full-on rainbow.

Performance is pretty impressive as well—with a lofty GPU overclock, the RTX 2080 Super's core remained at a maximum temperature of 49 C. Chuck a synthetic load on the processor and GPU at the same time to maximize heat output, and the Noctua NF-A12x25s easily manage to quietly keep thermals under control without even approaching what experienced gamers and enthusiasts would consider "loud."

The primary hurdle with a system like this—and it's a big one, particularly in times like these—is cost. The main components (sans cooling) in our build will set you back close to $3,010, but with all the liquid cooling and related bits on top of that, you'll be looking at a price tag of about $4,779 total, and that's if things are at their normal prices, not gouged by scalpers (thus the crazy street price right now of $6,504).

No one ever said custom, near-silent cooling on a high-end PC was going to be cheap. However, if you want to save yourself some time and money (OK, a lot of money), and don't mind taking a step down in the aesthetics department, you could opt instead for a good all-in-one cooler and a premium headset to drown out that extra fan noise. But if you do have the cash and time to spend on a custom loop, a system like our Mirror Maze will serve you well for several years to come, while standing out as a showpiece wherever you decide to put it. ⏻

# LAB NOTES

TESTED. REVIEWED. VERDICTIZED.

# Dreaming of the Future

## Planning for Dream Machine 2021

**DM 2017 was one of my favorite projects ever**

**IF YOU'VE READ** my "Editor's Intro," you'll know this has been one heck of a month for myself and the team. I've been stuck at home self-isolating, fighting off COVID-19, and Christian's also had to take a significant chunk of time out due to health concerns. It's been rough, for sure, yet also very moving to see how our publishing house and the wider industry has come to our aid. I can't thank the guys and gals at Tom's Hardware enough for their support—it's been invaluable. But I also want to apologize—when I first came on board, I promised two builds an issue, and this is the first time we haven't managed to hit that target (although I've got two epic builds lined up for the March edition).

That aside, stuck at home, trying not to infect my photographers, I got to thinking about the next Dream Machine, and how different it's going to be this year. We're holding out for the next generation of Threadrippers first—they ought to be something special, so will be the CPU of choice. But it's the GPU and storage that most interest me. SLI and Crossfire have officially departed this world. Nvidia only supports it on the RTX 3090, and is not providing any driver support (it's down to the game devs to do that), and with AMD, although DX12 supports multi-GPU setups, no major titles take advantage of that feature either. Meaning in the world of gaming, only one GPU really matters.

So, do we go for more than one? From a productivity level, it could make sense—videography, 3D rendering, and other simulation-based software would benefit, and Dream Machine has never been about realistic budget constraints. But I'm not certain, and open to suggestions. Then there's the question of storage. Having masses of local storage capacity seems old-school now. Wouldn't it make more sense to build an industrial-styled custom NAS alongside the Dream Machine? Or pick an overkill standalone product instead? So many questions, so little time.

## INDUSTRY INSIDER

This industry, as magnificent as it is, isn't without its flaws. One of the biggest problems is how some companies view tech journalists and, eugh, "influencers." Now, let's be clear, this isn't an attack on every company—there are a lot of decent people doing a stand-up job (the vast majority, in fact). But some bigwigs view tech journalism and reviewers as simply an extension of their own marketing departments.

All of a sudden, you get an angry email from a PR rep because you gave a product 4/10. Regardless of the fact the product was bad, they demand recompense otherwise they'll pull their advertising etc., etc., and it's this whole mess, and their bosses are shouting at them—but the reality is that in both PR and journalism, that's not how it should be.

After all, how could you blame a PR for bad coverage like that? Did they design the product? No. Their job should be to get coverage—not get good coverage and win awards—just get coverage, get feedback, and then report that feedback back to the design team. And yet so many businesses are run opposite to that when it comes to handling the media. Is it arrogance? Maybe. All I know is that it's incredibly frustrating. That's actually one of the big advantages of print—once the review's out there, it's out there. There's no coming back from that.

© GETTY IMAGES, ASUS

# Editors' Picks: Asus RT-AX88U

With its incredible looks, the Asus RT-AX88U also packs some amazing features—but what's causing the drops?

**I'VE BEEN HARD** at work tinkering with my home setup to try to get the most out of it now I'm more housebound. At the moment, I'm one of the lucky ones—I've managed to nab myself a 100Mb/s line for my day-to-day activities (I live somewhat out in the wilderness). It's not fiber (which I dream of), but it's more than ample for my work life and free time.

I've changed out all the cables in my home to Cat7 (the stock cable my ISP provided, to go from the socket to the modem, was a non-twisted pair Cat5e cable, which I didn't think existed anymore), then from the modem I plug directly into an Asus RT-AX88U router.

This is a gluttonous product, for sure. It rolls in at $350, features support for Wi-Fi 6.0 AX, and comes with a ton of features (including integrated VPN support), and one of the smoothest GUIs I've ever had the pleasure of using on a wireless router (it looks epic, too). I felt this was a necessary investment at the start of 2020, because I have quite the smart home at this point. My fiancée and I live in a relatively small property, and it's filled with a ton of devices—in fact, the total number of connections currently sits at 30. I've even put together a lamp specifically to illuminate my bonsai tree during these winter months, which also features a smart bulb that runs on a schedule, so the tree thinks it's summer.

But I'm having trouble, particularly with random disconnects while we stream Amazon Prime content on the TV, or if I'm in a Google Hangout meeting or Zoom call—the entire thing goes offline and disconnects either just me or the whole house for anything from 5–10 seconds (with VoIP) to 5–10 minutes (when streaming Prime). It's odd, and only started recently. According to my system log reports, Google's awash with accounts of firmware bugs and frustrations, so I'm not the only one experiencing this. Fortunately, at the time of writing, a new firmware has just been launched, which I'll install today, and that should hopefully fix my issues. Otherwise, I'll have to go back to a 2019 variant (one that I've been informed works fine), and just live with the security holes, which is a less-than-stellar idea, but should ensure all my devices stay connected without a hitch.

That said, all in all, it's a stunning piece of gear when it works correctly. The AI protection stuff has already stopped the future Mrs Storey from contracting several iPhone-based malwares, and the feature list is staggering. It's even compatible with my Amazon Echo devices (which does seem odd), and the ability to just enable ExpressVPN, NordVPN, or whatever you use across all your devices that are connected to the network is a cool idea, too (although it could do with an on/off switch per device, I think).

There are two other variables in my networking woes, however. Thinking specifically of the Google Hangout and Zoom drops, it's occurring on my main work rig, which is connected via a Netgear GS908E Switch (the one in my office) to that router. Again, I've only just started having these issues, 13 months into owning this router. The problem is it's incredibly difficult to diagnose. Is it my line to the house, my modem, my router, my switch, the cables, my Ethernet drivers, a Windows update? The list is endless. I'm half tempted to throw the lot out and start from scratch. **–ZS**

$350, www.asus.com

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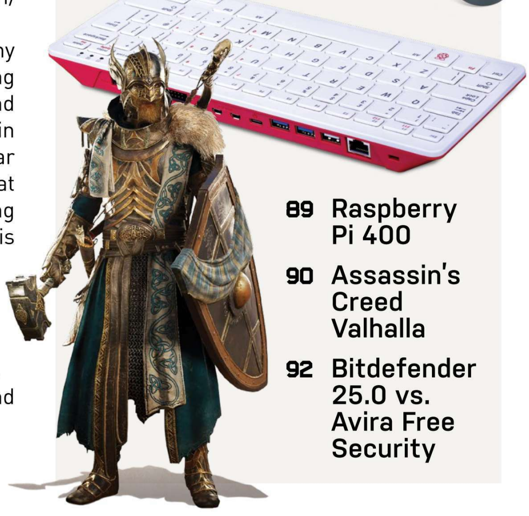

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# AMD Radeon RX 6900 XT

## Diminishing returns at the top of the product stack

**THEY SAY** imitation is the sincerest form of flattery. If so, the Radeon RX 6800 XT must be feeling pretty dang good about itself. Nearly every aspect of the reference RX 6900 XT is the same as the RX 6800 XT, except it has 80 CUs instead of 72. That means at best we'd expect a 10 percent bump in performance; in practice it's often less. Along with the incremental increase in shader core counts comes a painful 50 percent jump in price.

Everything good that we said about AMD's RDNA2 architecture still applies. The Infinity Cache means the 512GB/s of memory bandwidth can still compete with Nvidia's 936GB/s. But all the bad bits with RDNA2 remain unchanged. That means the RX 6900 XT is the fastest GPU in some games, such as the AMD-promoted *Assassin's Creed Valhalla*. However, flip to an Nvidia promotional title, such as *Control* or *Watch Dogs Legion*, with DirectX Raytracing (DXR) enabled, and it's not even close—and that's without turning on DLSS.

Your feelings toward AMD's RDNA2 GPUs will largely hinge on whether you think ray tracing and DLSS are the wave of the future, or if you're happy sticking with rasterized native rendering. Even if you don't care about RT and DLSS, there are still games where Nvidia's RTX 3080 and 3090 do better at 4K rendering, thanks to their added bandwidth. That big 128MB Infinity Cache can only carry AMD so far, and 4K performance suffers a bit, even though the 16GB capacity is otherwise quite generous.

The 3090, of course, is by no means a stunning deal either, but at least it gave users something tangible over the RTX 3080. Nvidia more than doubled the amount of VRAM, and that makes the RTX 3090 a powerhouse for many content-creation and professional workloads. AMD doesn't have support in quite as many professional applications either yet, so there are plenty of apps where Nvidia's RTX cards come out way ahead.

Blender, for example, has the RTX 3090 performing anywhere from two to five times as fast as the 6900 XT—even the RTX 3080 is over twice as fast as the 6900 XT on average. SPECviewperf 13 tells a different story, however, and AMD's 6900 XT chalks up wins in just over half the tests (catia-06, energy-02, medical-02, snx-03, and sw-04). If any of those falls under your list of important apps, AMD might be the better choice as well, though it's worth noting that a true professional card, such as a Quadro RTX, might be an even better choice in that case.

Unfortunately, availability of the RX 6900 XT appears to be even worse than Nvidia's Ampere GPUs. Two key factors are in play. First, 6900 XT uses the full Navi 21 GPU, so yields are much lower than for the 6800 XT and 6800. Second, TSMC has so much demand for its leading-edge N7 and N5 nodes that it can't keep up. AMD, Apple, Nvidia, Qualcomm, and others are using N7, and AMD has to split its share of wafers between the new Xbox and PlayStation APUs, Ryzen 5000 CPUs, and Radeon RX 6000 GPUs. One rumor says that 80 percent of the silicon wafers AMD is getting from TSMC right now is for the consoles, leaving CPUs and GPUs to fight for the scraps, and AMD is probably using more of the remaining wafers on Ryzen than Radeon.

If you want the fastest current AMD GPU, the RX 6900 XT fits the bill. Whether or not you'll be able to find one is another matter, almost regardless of how much you're willing to pay. We've seen custom RX 6800 XT cards with $900 recommended prices, which makes us wonder how much custom 6900 XT cards will cost. Considering the 6900 XT is only 5-7 percent faster than the 6800 XT, it's not worth the added cost. **–JARRED WALTON**

VERDICT
7

**AMD Radeon RX 6900 XT**

**+ FLATTERY** Lots of VRAM; high clock speeds; good rasterization performance.

**− IMITATION** Incremental gains; weaker ray tracing; no Tensor-like cores.

$999, www.amd.com

### BENCHMARKS

| | AMD Radeon RX 6900 XT | AMD Radeon RX 6800 XT | Nvidia GeForce RTX 3090 |
|---|---|---|---|
| 10-Game Average | 125/97/56 | 120/91/52 | **132/107/67** |
| Assassin's Creed Valhalla (DX11) | **124/101/61** | 119/96/59 | 93/81/57 |
| Borderlands 3 (DX12) | **173/132**/75 | 164/122/69 | 164/128/**76** |
| Control (DXR) | 63/40/20 | 60/38/19 | **108/72/36** |
| Cyberpunk 2077 (DX12) | **104**/75/38 | **104**/74/38 | **104/87/47** |
| The Division 2 (DX12) | **194**/134/70 | 188/128/67 | **194/143/81** |
| Red Dead Redemption 2 (Vulkan) | 129/109/73 | 124/102/68 | **136/117/83** |
| Watch Dogs Legion (DXR) | 56/39/21 | 51/35/18 | **81/61/35** |

Best results are in bold. Our test bench consists of a Core i9-9900K, MSI MEG Z390 ACE, 2x 16GB DDR4-3200 CL16, 2TB XPG 8200 Pro M.2 SSD, Seasonic Focus G 850W. Scores show average fps at 1080p/1440p/4K @ Ultra settings. *Cyberpunk* was tested without ray tracing enabled as AMD currently doesn't support it.

### SPECIFICATIONS

| | |
|---|---|
| GPU/Architecture | Navi 21 XTX |
| Lithography | TSMC N7 |
| Core/Boost Clock | 2,015/2,250MHz |
| Memory | 16GB GDDR6 |
| GPU Cores | 5,120 |
| Single Precision | 23 TFLOPS |
| TDP | 300W |
| Display Connectors | DisplayPort 1.4,<br>HDMI 2.1 |

It looks and behaves like the RX 6800 XT; it's just a bit faster thanks to the extra cores.

# Nvidia GeForce RTX 3060 Ti

## The new king of the price-to-performance hill

**WATCHING** the fastest GPUs trade blows is all well and good, but many of us prefer to stick with something more affordable. As we see elsewhere, with the RX 6900 XT, moving up the product stack often requires increasingly large sums of money for decreasingly small gains in performance. What that means is that the best options, in terms of bang for buck, are often a few steps down from the top dogs. If you've been watching the new Ampere and RDNA2 GPUs, and wondering when we'll get a mainstream option, you're in luck, because the RTX 3060 Ti is here.

Built on the same GPU and card design as the RTX 3070 we looked at last month, the RTX 3060 Ti has fewer cores and shaders but makes up for it with a $100 price cut. We could debate whether $400 represents mainstream pricing or not, but the RTX 3060 Ti easily wins against the RTX 2060 Super and RX 5700 XT, at the same asking price. It even beats last year's RTX 2080 Super, in both traditional and ray-tracing performance.

Naturally, the RTX 3060 Ti still includes all the Ampere features, such as second-gen RT cores and third-gen Tensor cores. It's surprisingly close to the RTX 3070 in performance, too, probably because it has the same memory configuration; 8GB on the $500 3070 felt a bit limiting, but it's easier to justify with the 3060 Ti. Not that we wouldn't like more VRAM—there are games where 8GB isn't quite enough to handle maxed-out settings—but a wider bus dramatically increases prices, and moving to 16GB for a mainstream card seems greedy.

We've only included benchmarks for the RTX 3060 Ti and 3070, with AMD's RX 6800. These are all new cards, and they're the best alternatives right now. Since the 3060 Ti is a trimmed-down version of the GPU used in the 3070, that means it doesn't come up with any performance wins. Rest assured, it beat the RTX 2080 Super in nearly every test we ran, with an overall lead of 5 percent. That might not seem like much, but for a card that costs 40 percent less, it's more than enough to take the crown as the best value option right now (in FPS per dollar spent). It's also 20–30 percent faster than the RX 5700 XT, and 35–45 percent faster than the 2060 Super, and if you want to go back another generation, the 3060 Ti is twice as fast as the old GTX 1070.

If you have a previous card that's still meeting your needs, there's no immediate need to upgrade to the 3060 Ti, but anyone in the market for a GPU upgrade definitely shouldn't be eying previous-gen hardware. AMD hasn't announced a new RDNA2 GPU at the $400 price point, which means Nvidia is basically the only reasonable option for now. But will you actually be able to find a card in stock?

That's a more difficult question. Considering even previous-gen hardware is currently selling at prices higher than the original MSRPs, things aren't looking good. However, one retail outlet did say it received more RTX 3060 Ti cards for the launch than all of the previous RTX 30-series GPUs combined. It still wasn't enough, but we expect Nvidia planned on selling far more mainstream GPUs than high-end and extreme GPUs, so hopefully by the time you're reading this, not every 3060 Ti will be back-ordered.

One final thing to keep in mind is that the next step down in performance and price will likely make even more compromises. Could RTX 3060 stick with 6GB? If so, we think the 3060 Ti will be the superior choice. It's generally sufficient for 1080p gaming at 60fps, even with RT enabled (and DLSS in quality mode). We can't say the same for last year's 20-series hardware, especially in games such as *Cyberpunk 2077*. **–JARRED WALTON**

### BENCHMARKS

| | Nvidia GeForce RTX 3060 Ti | Nvidia GeForce RTX 3070 | AMD Radeon RX 6800 |
|---|---|---|---|
| **10-Game Average** | 91/68/39 | 100/76/44 | **103/78/45** |
| **Assassin's Creed Valhalla** | 75/61/39 | 80/66/43 | **105/84/50** |
| **Borderlands 3** | 103/74/42 | 116/85/48 | **139/103/59** |
| **Control** | 63/40/20 | **70/45/22** | 51/33/16 |
| **Cyberpunk 2077** | 79/52/26 | **90**/59/30 | 85/**60/31** |
| **The Division 2** | 129/87/46 | 144/99/52 | **163/108/56** |
| **Red Dead Redemption 2** | 87/72/49 | 97/80/54 | **107/90/61** |
| **Watch Dogs Legion** | 51/35/17 | **57/40/20** | 43/30/15 |

Best results are in bold. Our test bench consists of a Core i9-9900K, MSI MEG Z390 ACE, 2x 16GB DDR4-3200 CL16, 2TB XPG 8200 Pro M.2 SSD, Seasonic Focus G 850W. Scores show average fps at 1080p/1440p/4K @ Ultra settings. *Cyberpunk* was tested without ray tracing enabled, as AMD currently doesn't support it.

VERDICT
9

**Nvidia GeForce RTX 3060 Ti**

**+ GENEROUS** Excellent value; beats RTX 2080 Super; DLSS 2.0.

**− STINGY** 8GB; no bling; RT is demanding.

$399, www.nvidia.com

### SPECIFICATIONS

| | |
|---|---|
| **GPU/Architecture** | GA104 |
| **Lithography** | Samsung 8N |
| **Core/Boost Clock** | 1,410/1,665MHz |
| **Memory** | 8GB GDDR6 |
| **GPU Cores** | 4,864 |
| **Single Precision** | 16.2 TFLOPS |
| **TDP** | 200W |
| **Display Connectors** | DisplayPort 1.4a,<br>HDMI 2.1 |

It looks virtually identical to the RTX 3070, right down to the questionable 12-pin power connector.

It certainly looks the part, but then it should—it's $400.

# Asus ROG Crosshair VIII Dark Hero

## A Ryzen 5000 series refresh, but does the "Dark" matter?

**IN THE MIDDLE** of last year, we took a look at the original ROG Crosshair VIII Hero from Asus. It was an exceptional piece of engineering, with a ton of potent connectivity, and it performed well combined with a Ryzen 7 3700X. However, it came with one major caveat: The cost. Back then, we lamented the slow creep of that price tag with generation after generation of Asus's products. Indeed, the X370 Hero launched at $255, the X470 at $285, and the latest-generation Hero tipped the scales at an incredible $360 ($380 if you wanted Wi-Fi).

There's an argument to be had that the PCIe 4.0 connection standard is far more difficult to produce, and we have seen price increases across the board from all manufacturers, but X570 has been out for some time now, and as with all things in the world of tech, the longer it's around, the easier it typically becomes to manufacture, which in turn should also make it cheaper to produce. Take a look at DDR4 and PCIe 4.0 SSDs as an example.

So, how much does Asus's latest X570 Hero refresh (released in time for the 5000 series processors) cost? $400. That's an extra $40 on top of the already solid X570 solution, or $20 more compared to the old VIII Hero Wi-Fi variant.

And what extras do you get compared to the standard Hero? As far as our eagle eyes can spot, not a whole lot. Almost the entire PCB layout is identical. Chip placement, M.2 layout, SATA ports—it's almost all the same. Every single piece is darn-near identical, bar a few little tweaks here and there. Asus has finally managed to get rid of that pesky chipset fan with a gargantuan heatsink, (although how it got that past AMD we don't know, because Team Red has been very particular about that chipset needing a fan since day one), and it's got a funky new "Dark" design on top. The 14+2 power phase delivery is also pretty much identical, except the MOSFETs have been upgraded and are now capable of handling 90A each instead of 60, which is overkill. The audio solution is still the same; in fact, the rear I/O is identical (compared to the Hero Wi-Fi variant). So, at this point, we can safely assume that if you have the Crosshair VIII Hero, you don't need this board, unless you're building a second system, or that chipset fan really annoys you. Even then, given the price tag, that would be a very gluttonous solution to that problem.

It is still an incredibly good board. If you haven't upgraded for some time, it has all the bells and whistles you could want from a mobo, including solid M.2 heatsinks, a fantastically clean aesthetic, expert memory support, one of the best BIOS UIs we've ever seen, a ton of I/O at the rear and on the board, and some very nice lighting, too. As for performance, it does about what you'd expect, really. With our Ryzen 7 3700X test bed, we achieved 43.4fps in Tech ARP's x264, 2,167 in Cinebench R15, and, well, we'll leave the charts to do the rest of the talking. Simply put, it applies voltage well, and gives us figures consistent with what we'd expect, especially in the power draw department.

So, is it a good board? Yes. Does it justify another price increase? Perhaps. Will you be happy if you buy this board for your shiny new Ryzen 5000 system? Most certainly. The Crosshair VIII Dark Hero looks the part, comes with a ton of connectivity, and performs well, but it costs a lot—it was originally a mid-range board, but it certainly isn't now. This is a high-end product, and as far as we can tell, this is a pricing trend we're seeing across all of the product stack. R&D costs are steep, sure, especially when dealing with a new chipset on a new platform, but it's not a new platform now, and if we're honest, this ain't it, chief. **–ZAK STOREY**

**VERDICT**

**7**

**Asus ROG Crosshair VIII Dark Hero**

**+ EXCEED** Strong performance; impressive aesthetics; no chipset fan.

**− GREED** Price hike (again); power-delivery overkill.

$400, www.asus.com

### BENCHMARKS

| | Asus ROG Crosshair VIII Dark Hero | Asus ROG Crosshair VIII Hero |
|---|---|---|
| Tech ARP's X264 (fps) | **43.4** | 43.3 |
| Cinebench R15 Multi (Index) | 2,167 | **2,172** |
| Fry Render (m:s) | **1:58** | **1:58** |
| AIDA64 Memory Latency (ns) | **74.3** | 74.9 |
| CrystalDisk QD32 Sequential Read (MB/s) | **5,013** | 4,997 |
| CrystalDisk QD32 Sequential Write (MB/s) | 4,403 | **4,452** |
| Power Draw Idle/Load (Watts) | **58**/153 | 59/**152** |
| Total War: Warhammer II (fps) | **58** | **58** |
| Lowest Voltage @ 4.2GHz (Volts) | **1.07** | **1.07** |
| Maximum OC Achieved @ 1.08V (GHz) | **4.3** | **4.3** |

Best scores are in bold. Our test bed consists of an AMD Ryzen 7 3700X, 32GB of Corsair Dominator Platinum RGB @ 3600, an Nvidia GeForce GTX 1080, and a 2TB Corsair Force MP600 NVMe Gen4 SSD. *Total War: Warhammer II* was tested at the ultra preset at 1440p.

### SPECIFICATIONS

| | |
|---|---|
| Chipset/Socket | X570/AM4 |
| Max Memory Support | 128GB (4x 32GB) @ 4800 |
| Storage Support | 8x SATA, 2x M.2 PCIe 4.0 |
| PCIe Support | 2x PCIe 4.0 x16 (x8x8) |
| Form Factor | ATX @ 12 x 9.6 inches |
| Rear I/O | 11x USB 3.2 Type A,<br>1x USB 3.2 Type C,<br>Intel Gigabit Ethernet,<br>2.5G Ethernet,<br>5.1 audio-out,<br>optical audio-out,<br>Clear CMOS button,<br>BIOS Flashback button,<br>Wireless A/X |

# ViewSonic VP2785-2K

## Intriguing alternative for content creation

**REMEMBER WHEN** 1440p was the latest thing? An exciting and exotic step up from 1080p, not distant second fiddle to fancy 4K? For proof that ViewSonic remembers, we present the new VP2785-2K.

It's an extremely well-specified 27-inch IPS monitor, packed with features including USB-C hub functionality and very impressive color coverage. But instead of the full UHD-spec complement of 3840x2160 pixels, it's pegged back to a native resolution of 2560x1440.

The most obvious upside is a lower price. At just over $500, it's not exactly cheap, but it does significantly undercut most 4K monitors with comparable features. The most obvious downside is the inability to view 4K content in full.

There are further consequences of the notional downgrade from 4K to 1440p, but before we ponder those, let's consider the VP2785-2K's wider qualities. Foremost is color coverage, calibration, and certification. ViewSonic says the IPS panel is good for 100 percent of the Adobe RGB space and 96 percent of DCI-P3. Both are available as presets in the comprehensive OSD menu, along with others. There's also factory calibration with a guaranteed Delta E below two.

There's 14-bit LUT support, too, generating a palette of 4.39 trillion colors. If all that is impressive but not entirely unusual, the addition of Fogra certification is special. The VP2785-2K is a Class A FograCert Softproof monitor, which implies a high level of reliability in terms of visual match between this display and printed materials.

For comparison, ViewSonic released a 4K version of this same 27-inch monitor with Fogra certification back in 2017, with a launch price of $1,200. Admittedly, the VP2785-4K has since fallen to well under $1,000, but it's still far more costly.

Color fidelity aside, the VP2785-2K's other worthy talent is USB-C connectivity, including support for daisy-chaining and device charging. That means you can use a single cable to hook up a laptop, drive two displays, connect peripherals, and charge the laptop itself. A serious boon for ease of use and cable management.

Rounding out the main features is a multi-adjustable stand that supports rotation into portrait mode. It certainly makes for a strong on-paper proposition with the only weak point being the rather ugly, clumsy external power brick (an integrated PSU would be preferable). As for design, slim bezels on three sides of the IPS panel ensure it's compact and contemporary, but the stand base is bulky and intrudes into desk space.

But what of the minor matter of how the VP2785-2K performs? Immediate impressions are mixed. Despite factory calibration, this panel's default balance is rather warm and suffers from slightly pink flesh tones. A little disappointing given the content creation and color-accurate remit. That said, with full hardware calibration support, dialing it in for a given workflow should be simple.

Otherwise, the image quality is pretty much what you would expect from a high-spec SDR monitor. It's vibrant and punchy, with good rather than great contrast, and excellent viewing angles, albeit with some transient and unavoidable IPS glow.

Of course, the 1440p rather than 4K native resolution makes for lower DPI and thus less visual sharpness and detail, not to mention less desktop real estate, but this is an attractive proposition at the price for content creation where the full 4K isn't required. **–JEREMY LAIRD**

VERDICT
9

**ViewSonic VP2785-2K**

**+ MORE THAN OK** Comprehensive feature set for demanding content workflows; USB-C connectivity.

**− NOT 4K** Not suitable for UHD content creation; disappointing default calibration.

$509, www.viewsonic.com

### SPECIFICATIONS

| | |
|---|---|
| **Panel Size** | 27-inch |
| **Panel Type** | IPS |
| **Resolution** | 2560x1440 |
| **Brightness** | 300cd/m$^2$ |
| **Contrast** | 1,000:1 |
| **Pixel Response** | 5ms |
| **Color Coverage** | 100% Adobe RGB,<br>96 percent DCI-P3 |
| **Refresh Rate** | 60Hz |
| **VESA** | 100 x 100mm |
| **Inputs** | DisplayPort 1.2,<br>2x HDMI 1.4, 1x USB C<br>with 65W charging |

ViewSonic's new 1440p 27-incher for creatives undercuts the 4K competition and includes USB-C connectivity.

The Pro 2 is a massive block of metal, glass, and plastic.

# Phanteks Enthoo Pro 2

## More drives! More drives!

**THE ORIGINAL ENTHOO PRO** is looking a little dated these days, with its cheap plastic construction and multiple optical drive bays (yikes), so Phanteks has rightly decided that it's time for a sequel. The Enthoo Pro 2 is a very different beast, falling squarely into the category of big, beefy PC cases capable of containing all sorts of systems.

Yes, we said "systems" plural. Dual-system support is one of the Pro 2's big draws, granting the ability to mount a secondary ITX system at the bottom of the case via the manufacturer's own Revolt X compact power supply. So, this case is nothing if not spacious, with room for a massive 480mm radiator at the front and a frankly absurd number of drive bays.

That's 23 drives in total, but you'll need to buy some extra drive mounts from Phanteks to achieve that. We have 11 2.5-inch SATA SSD mounts around the case, which are simple metal affairs where the drive is screwed into the bracket, then the bracket is mounted toollessly inside the Pro 2's metal frame. There's also space to mount up to 12 3.5-inch HDDs, although only four brackets are included at the base price. In other words, this case is ideal for home server builds, so anyone who handles large amounts of data should take note.

Regardless of what you choose to build in this Enthoo, it's sure to run cool. Heat management isn't an issue here, as the case is large enough to allow for superior airflow and augments this with a fabric mesh front panel. It's a bit unusual, but it actually filters fan noise well and a secondary synthetic mesh panel behind it serves to better filter out dust. The casing surrounding this fabric mesh is entirely plastic, which is a shame, since the rest of the chassis is crafted from more durable and better-looking materials, namely brushed aluminum and tempered glass.

Behind the motherboard mounting plate, the Enthoo Pro 2 has a variety of neat innovations. A hinged metal panel covers part of the PSU shroud here, secured with a single thumbscrew and enabling you to neatly bundle and conceal any excess power cables behind it. Velcro straps, neatly ordered routing channels, and metal cover plates do an excellent job of ensuring that good cable management in this case is quick and easy.

### OUTSIDE INTERESTS

On the exterior, we've got a solid front I/O concealed behind a plastic shutter (which looks like a hangover from the Enthoo's disk drive days). Four USB-A ports are joined by a lone USB-C and audio input-output, providing excellent physical connectivity if paired with a supported motherboard. There's also an RGB control button, which allows you to tweak any connected lighting along with the sleek LED lightstrip built into the case.

The Enthoo Pro 2 has plenty of space for fans (up to four 120mm fans behind the front panel, just to start with), but it's a shame it doesn't come with any actual case fans. It's not a deal-breaker, given that for a full-featured, full-tower case, it has a very reasonable asking price of $140, but the price of add-ons may stack up. Including fans, HDD brackets, vertical GPU mounts, and the secondary ITX PSU will drive the price up significantly.

If you've got the space for it, this is a great choice of case for a powerful gaming rig, workstation, or NAS build. Small desks beware, though—the Enthoo Pro 2 is a whopping great rectangle, measuring over 20 inches long and tall. Many simply won't require a case this size, and unless you absolutely need dual systems or tons of drive bays, a more sensible mid-tower case might be a better option, even considering the Pro 2's competitive price point. **–CHRISTIAN GUYTON**

VERDICT
**8**

**Phanteks Enthoo Pro 2**

**+ PROFESSIONAL** Good value; tons of drive space; feature-rich; good thermal performance.

**– AMATEUR** No included case fans; flimsy front panel; seriously bulky.

$140, http://phanteks.com

**SPECIFICATIONS**

| | |
|---|---|
| **Form Factor** | Full tower |
| **Motherboard Support** | E-ATX , ATX, microATX, Mini-ITX, SSI EEB |
| **Colors Available** | Black |
| **Window Available** | Yes |
| **3.5-Inch Support** | 12 (4 included) |
| **2.5-Inch Support** | 11 |
| **Radiator Support** | 480mm (front),<br>360mm (top),<br>140mm (rear) |
| **Fan Support** | 4x 120mm (front),<br>3x 140mm (top),<br>1x 140mm (rear) |
| **Dimensions** | 9.5 x 22.8 x 22 inches |
| **Graphics Card Clearance** | 19.8 inches |
| **CPU Tower Clearance** | 7.7 inches |
| **Weight** | 33.1lb |

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# Corsair MP400 2TB

## Lots of cache for not much cash

**GEN-THREE PCIE.** QLC. Up to 8TB. Five-year warranty. We give you the new Corsair MP400, summed up in soundbites. Reducing a product as complex as an SSD into a few phrases obviously isn't the whole story, but those headline features do give you a pretty good idea of what you can expect.

Thus, this is a PCIe 3.0 rather than 4.0 drive. Consequently, Corsair pegs sequential read performance at 3,480MB/s for all variants of this drive. The 2TB version tested here, meanwhile, is said to be good for 3,000MB/s of writes. As for random 4K read performance, 380,000 IOPS is your lot with this 2TB drive, with 4K writes rated at 560,000 IOPS.

That's all enabled by the E12S iteration of Phison's widely used PS5012 eight-channel NAND memory controller. Of course, arguably the MP400's defining feature is the use of QLC or quad-level NAND flash memory. The upside is more capacity for less cash compared to NAND memory, with fewer bits per cell. But as with every increase in per-cell data density, QLC memory comes at a cost in the form of lower performance and less endurance.

By way of comparison, Corsair rates the MP400's write endurance at 400TB, while a high-end TLC drive, such as the Samsung 980 Pro in 2TB format, is good for 1,200TB of writes. Before the panic sets in, that 400TB figure allows for 100GB of writes each day, every day, for 10 years. Or twice that much data every day for five years, which, as it happens, is the longer-than-usual duration of the MP400's warranty. In other words, despite the use of QLC NAND, endurance oughtn't be a major concern. Performance, on the other hand…. Now, that might be.

The peak sequential figures of 3,480MB/s read and 3,000MB/s write look healthy enough for a PCIe 3.0 drive, but that performance only extends to the drive's SLC cache, which is a dynamically sized portion of the QLC memory running in faster single-level mode. With a drive of this capacity, it's possible to offer significant quantities of SLC cache.

## REPEAT PERFORMANCE

Corsair doesn't quote either the underlying performance of the QLC memory or the maximum size of the SLC cache. However, in our testing, performance dropped off dramatically to around 240MB/s after approximately 250GB of writes, implying both the maximum size of the cache and the underlying performance of the QLC NAND.

If that sounds like plenty of high performance cache to be getting on with—and it is—the problem obviously comes as the drive fills with data. It's not clear exactly how Corsair manages the SLC cache, but we suspect cache availability and thus sustained performance is probably impacted beyond 50 percent storage capacity.

Whatever, we've no complaint concerning peak performance, which pretty much tallies with Corsair's claims. 4K random write performance is also very strong, with the MP400 achieving 215MB/s at queue depth one, perhaps reflecting the 1GB of DDR4 DRAM. 4K random reads of 59MB/s are more in line with what you'd expect from a value-oriented drive.

Our early impressions of the first QLC SSDs were not hugely favorable. They weren't particularly cheap compared to the TLC alternative, and the performance penalty was all too obvious. But at larger multi-TB capacities, the technology is coming good.

Hundreds of gigabytes of SLC cache means performance for most users is excellent, while the sub-$250 price makes mass solid-state storage a realistic option. We're likewise impressed by the MP400's five-year warranty, which neatly deals with the last remaining concern regarding QLC NAND memory, namely long-term reliability. The only catch is that there's a few remaining TLC-based drives priced within close proximity, though those drives, such as the WD Blue SN550, tend to be DRAM-less. That caveat aside, this is a very appealing SSD. **–JEREMY LAIRD**

**VERDICT**
**9**

**Corsair MP400 2TB**

➕ **NOT MUCH CASH** Strong peak performance; lots of SLC cache.

➖ **WASTE OF CACHE** Performance eventually drops off; similar cost as some TLC drives.

$244, www.corsair.com

**BENCHMARKS**

| | Corsair MP400 2TB | Samsung 970 Evo Plus 1TB |
|---|---|---|
| CrystalDisk 6 Sequential Read/Write (MB/s) | **3,473/3,037** | 2,788/2,331 |
| Anvil 4K QD 1 Read/Write (MB/s) | **59/215** | 48/141 |
| Anvil 4K QD 2 Read/Write (MB/s) | **119/316** | 91/281 |
| Anvil 4K QD 4 Read/Write (MB/s) | **228/665** | 152/524 |

Our test bench consists of an AMD Ryzen 9 3800X, an Asus Crosshair VIII Hero, an Nvidia GeForce GTX 1080, 16GB of Corsair Dominator Platinum DDR4, and a Samsung 850 Evo 250GB OS SSD. Best scores are in bold.

**SPECIFICATIONS**

| | |
|---|---|
| Capacity | 2TB |
| Format | M.2 2280 |
| Interface | PCIe 3.0 x4 |
| Read/Write | 3,480/3,000MB/s |
| Memory | QLC NAND |
| Controller | Phison PS5012 8-channel |
| Write Endurance | 400TB |
| Warranty | 5 years |

# Corsair HS70 Bluetooth

## A no-nonsense, versatile headset

CORSAIR
//70BT

**CAST YOUR MIND BACK** six years. It's 2015, Tom Brady's... well you know, have been brought into question, the legendary Leonard Nimoy has passed away, the Apple Watch has just gone on sale, and everyone's rocking a Core i5-4690K and Nvidia GTX 970 as the ultimate 1080p gaming rig.

In the world of headsets, however, there's not much going on. SteelSeries has some stellar products, Razer's got those bass-heavy muffled early Krakens, and Corsair has some very solid-looking units, but on the whole, when it comes to bang-for-buck, Kingston HyperX is the name of the game. Specifically with its Cloud headset. Fast-forward five years and things have changed quite dramatically. The market has been flooded with headsets at this sub-$100 price point, with each manufacturer and product line trying to carve out a chunk by edging out the others and convincing you to part with your hard-earned cash in an increasingly small playing field.

What we're trying to say is that right now, it's difficult to stand out. And as tech and connectivity production costs continue to fall, we're starting to see a lot of promise in this particular field. Headphones that once would have cost $200-plus, are now half that, and the sound quality that accompanies them has also exponentially improved year on year. Nowhere is this more apparent than with Corsair's HS70 Bluetooth headset.

Straight out of the gate, they adhere to Corsair's new design philosophy, mixed with a bit of the HS series of old. That means no RGB, no frills, no nonsense, just pure simple clean design, with the new logo, and some new subtle touches. We're talking comfortable earcups, faux leather, memory-foam padding, a sturdy metal frame, and solid quality 50mm neodymium drivers, albeit with a fairly basic frequency response.

As far as the sound goes, it's not mind-blowing (audiophile) level, but let's be clear, this is a $100 headset with a plethora of other features to sink your teeth into, and there's only so much you can do with such a limited budget. That said, it is an all-around solid profile. There's not too much bass, not too much treble, and it's all well rounded, with a slight leaning to the bottom end. As with the HS60 Haptic we looked at a few issues ago, it really benefits from some EQ profile tinkering in iCUE.

The real USP, however, is the connectivity, and, oh boy, does it have some. In fact, it comes with support for 3.5mm, USB, and Bluetooth as standard. On top of that, you can run two of these connectivity standards at the same time. Plug in via USB to your PC, and connect via Bluetooth to your phone to answer calls, or log in via Discord (or your preferred VOIP software) instead. This isn't the first time we've seen this, but most of those products with dual connectivity were well over the $140 price mark.

All in all, it's a solid headset, with a strong sound stage, and an impressive swathe of connectivity. Perhaps the only criticism we do have is that if you want to enable iCUE's EQ editing abilities, you need to plug in via USB to your PC. And there's no onboard memory, either, so if you do take it out on the road, and plug in via analog or Bluetooth, you're back to that flat EQ once more, which is a bit of a shame. Perhaps that's the next step for multi-connectivity headsets like these: Just a small memory chip with a couple of KB of storage to keep your EQ and lighting profiles on, similar to a keyboard. Nonetheless, if you've tried the Corsair HS-series headsets before, and have a liking for them, you'll equally enjoy the HS70 Bluetooth. It's very similar, yet comes with a slightly tweaked sound stage, updated branding, and a ton of extra connectivity for any and all of your devices. **–ZAK STOREY**

**VERDICT 8**

**Corsair HS70 Bluetooth Headset**

**+ HEROIC SONATA** Strong sound stage; good price; removable mic; comfortable; connectivity is huge.

**– HARPY'S SHRILL** No EQ storage; Bluetooth won't connect to PC.

$100, www.corsair.com

### SPECIFICATIONS

| | |
|---|---|
| **Driver Type** | 50mm dynamic neodymium |
| **Frequency Response** | 20Hz–20kHz |
| **Sensitivity** | 109dB (+/-3dB) |
| **Design Style** | Closed |
| **Microphone Type** | Removable unidirectional |
| **Connection Standard** | 3.5mm, USB, Bluetooth |
| **Battery Life** | 30 hours |

# SteelSeries Sensei Ten

## An old favorite gets a new coat and sensor, but is it enough?

**THE SENSEI** from SteelSeries has been a favorite for many a gamer since the original was released back in 2011. Its predecessor, the Xie, released in 2009, was very similar to the Sensei—almost like a prototype—but since the Sensei itself was born, it has continued to evolve over the years. The original shape was a big hit and although the Sensei 310 did have a change of form, there was uproar from the community and, with the Sensei Ten, SteelSeries has now reverted to what customers know and love.

Using the Ten is like meeting an old friend—you know what to expect and it's almost as though you've never been apart. We get the feeling there is a trip down memory lane to be had with flashbacks of *Battlefield 3.* There are a few changes, however. A soft touch coating has been applied to all sides apart from the bottom, and although this does make the mouse feel silky smooth, it also makes it a little more slippery, and only time will tell how it will hold up to the hours of intensive gaming that the mouse deserves. The ambidextrous shape of the Sensei lends itself to any grip style, and the eight programmable buttons are easy to reach from the smallest to the largest of hands.

A TrueMove Pro sensor lies under the hood, and although there is very little information from the manufacturer, it seems that after comparing spec sheets, it's based on the PixArt 3389/3390. This is backed up by the performance, because it worked flawlessly in all of our testing. There was no stutter or ghosting, and it had no problem tracking on the multiple surfaces that we tested it with. SteelSeries has always targeted the FPS genre with the Sensei range, so that's where we focused the majority of our testing; although it isn't as light as some of the ultra-light mice on the market, it is still light enough for those coveted 360 no-scopes and flick shots.

As it's 2021, it comes as no surprise that RGB lighting is incorporated, but it's only the logo and scroll wheel that illuminate. If you're after something that lights up like a Christmas tree, this won't be the mouse for you. The colors are vivid, though, and easily changed within the SteelSeries Engine 3 software. While on the subject of the software, it's so intuitive it doesn't matter if it's the first time you've used it, or if you're an old pro. It might not be our favorite software suite, but it certainly sits in the top three.

## FAMILIAR VALUES

All in all, the Sensei Ten is certainly a contender to be one of the best mice around, but it isn't without its faults. The cable is rather stiff, the soft-touch coating is a little too soft, and when some other competing mice with similar specs cost as little as $50, $70 is a bit hard to swallow. Having said that, SteelSeries Engine 3 checks the right boxes when it comes to software. It's intuitive, easy to use, and also looks the part. The sensor is fantastic, and those who love the Sensei shape will certainly feel at home with this. If you've never used a previous Sensei, you will still likely find it familiar; many other mice took inspiration from the series, and some blatantly copied the design.

Of course, mice are very much down to personal preference, and we always suggest getting hands-on with them before purchase. When a company returns to the same shape it was producing nine years ago, it means it has confidence in its product, and after spending a while with the Sensei Ten, we have confidence in it, too. **–DAVE ALCOCK**

**VERDICT**

**8**

**SteelSeries Sensei Ten**

⊞ **SUPER SENSEI** Great sensor; familiar shape; intuitive software.

⊟ **SILLY STUDENT** Slippery texture; not for those with a tight budget.

$70, www.steelseries.com

### SPECIFICATIONS

| | |
|---|---|
| **Sensor Model** | TrueMove Pro |
| **Max Sensitivity** | 50–18,000 in 50cpi increments |
| **IPS** | 450 |
| **Acceleration** | 50G |
| **Programmable Buttons** | 8 |
| **Connection Standard** | USB 2.0, 6.75 feet |
| **Battery Life** | N/A |
| **Weight** | 0.2lb |

# Razer Cynosa V2

## A $60 keyboard from Razer?

**RAZER IS RENOWNED** for its peripherals, its cult-like fan base, and, of course, its RGB lighting. Razer spends its marketing budget very well; even those who have never or will never use its products see the Razer logo and branding all over the place, from Twitch streams to YouTube ads, TV, and more. This means that impressionable young minds see their heroes playing on a $200 keyboard, then have to have one. Often, parents don't understand the need for expensive keyboards, can't afford them, or simply, don't want to buy them for younger children. Equally, there are many adults who don't understand the mechanical keyboard hype, but still want the rest of the features Razer offers. This is where membrane keyboards hold their own. For $60, you can get a Razer keyboard with the majority of the features the top-end mechanical boards boast, but at a fraction of the price. The main difference, of course, is that the switches are membrane, rather than mechanical.

The newest membrane keyboard from Razer is the Cynosa V2. This is an upgraded version of the original Cynosa, and it now comes with dedicated media keys and volume control. The Cynosa V2 has three cable routing options, ensuring your desk stays as clear as possible, plus dust and spill resistance. This is ideal if you have younger sticky fingers around the keyboard. Of course, the Cynosa V2 has Chroma RGB, and—surprisingly—individually backlit keys, as opposed to three zones, like the comparable Corsair option, the K55. This doesn't sound too impressive, but when combined with the Razer Chroma integration, there are some popular games that can control the lighting and customize them, depending on what's happening in-game. It is rather gimmicky, but it's also appealing, especially to a younger market.

Unlike the K55, the Cynosa V2 doesn't have any dedicated macro keys, but each key can be individually reprogrammed with a whole host of functions: Windows shortcuts, profiles, software launch options, and more. To do this, you have to use Razer Synapse, which isn't our favorite software, but equally, it isn't terrible. If you get used to it and have multiple Razer products, it's fine.

### FONT OF WISDOM

Typing on the Cynosa V2 is as you would expect from a membrane keyboard—it's squishy, cushioned, and has some resistance and a bump when the keys are pressed. There is no click or audible cue that there has been an actuation, which could appease office workers. Typing on a membrane board is fine if you don't know any better, or if you don't like mechs. If you have found your end-game switch, however, it feels awful. The keycaps are ABS and have a nice legible font on them, a far cry from the old "gamer" font that was usually found on cheaper keyboards aimed at a younger audience.

Basically, this board is all about its target audience. There isn't anything wrong in terms of function, and despite a little flex if you try to twist the board, it isn't any worse than some mechanical boards. The Cynosa V2 actually boasts many of the same features as a lot of the Razer mechanical boards, with really the only major difference being the obvious lack of mechanical switches. If a mech isn't wanted or needed, or you don't have the budget for one, this is a great alternative, especially if you want fantastic RGB lighting, dedicated media and volume keys, and easy-to-read legends. Sure, the Corsair K55 is $10 cheaper, but let's face it, if you or your young ones are set on Razer, and you don't want to spend a fortune, this checks the boxes. Although the per-key lighting isn't really needed, it offers some nice customization options that, as young teens, we would have loved. **–DAVE ALCOCK**

**VERDICT 8**

**Razer Cynosa V2**

**+ SHARP RAZER** Per-key lighting; dedicated media keys.

**– DULL BLADE** $10 more than the competitor product; no onboard memory.

$60, www.razer.com

**SPECIFICATIONS**

| | |
|---|---|
| **Form Factor** | Full-size |
| **Switch Type** | Membrane |
| **Switch Durability** | N/A |
| **Media Keys** | Stand-alone |
| **Connection Standard** | USB 2.0 |
| **Battery Life** | N/A |
| **Weight** | 29.9oz |
| **Dimensions** | 6.6 x 18.3 x 1.2 inches |

# Raspberry Pi 400

## Pi inside a keyboard? Yes please

**THE RASPBERRY PI MODEL B** has had the same board layout since the Pi B+ arrived in 2014. So, when we received a parcel from Raspberry Pi Trading and opened the box to find a white keyboard, we were somewhat puzzled as to the contents. But not for long. Within this compact and well-designed keyboard is a Raspberry Pi 400, a variant of the Raspberry Pi 4 4GB that's been designed specifically to make the most of its new surroundings.

The device is sold as a single unit for $70 or as a $100 kit with mouse, power supply, cables, microSD card, and a copy of *The Official Raspberry Pi Beginner's Guide*. Either way, the Pi 400 is an ideal way to introduce the Pi to your home.

If you're of a certain age, you'll remember when computers were hidden beneath a keyboard. The Pi 400 brings that aesthetic back and it works well. The compact keyboard measures just over 11 x 4.6 x 0.7 inches and is fairly comfortable to type on. We won't be writing our next thesis with this keyboard, but it's fine for daily use. At the rear of the keyboard are all of the ports, the largest of which is a 40-pin header for the GPIO. Moving along we find a microSD card slot, two Micro HDMI ports that offer 4K output, two USB 3.0 ports, and a single USB 2.0 port, with a Gigabit Ethernet port rounding off the Raspberry Pi 400's range of inputs.

Despite the change in form factor, this is still a Raspberry Pi 4 4GB and as such it behaves in much the same manner. There are a few differences, though. The Pi 400 lacks the CSI and DSI connectors that are used for the Camera and Official Touchscreen. Without these connectors, there's no way to use those devices. This loss of the touchscreen connector isn't such a big deal, but the same can't be said about the loss of the camera connector. The Raspberry Pi cameras are cheap and effective add-ons that provide a fun stream of projects. Essentially, if you want to create camera projects, the Raspberry Pi 400 isn't for you.

Accessing the GPIO is relatively easy. You can use jumper wires to make connections to a breadboard, but connecting a HAT or pHAT isn't possible without a breakout board, such as Pimoroni's HAT Hacker HAT.

The Raspberry Pi 400 shares the ability to boot from USB. We attached an NVMe drive containing Ubuntu 20.10 via USB 3 and the Pi 400 booted directly from it. There were no issues and our experience was pretty slick.

At its heart, the Raspberry Pi 400 is a Raspberry Pi 4 and it's well known that the Pi 4 can become rather warm. In general use, though, the CPU stays cool enough to remain well under the thermal throttle limit of 85 C.

The stock speed of the Pi 400 is 1.8GHz. That's 300MHz more than the standard Raspberry Pi 4, so it's surprising that the idle temperature of the Pi 400 is 31 C, compared to our "control" Pi 4 at 40 C. During our Stressberry test, we saw the Pi 400 reach a peak of 46 C. That's almost 20 C lower than a stock Pi 4. We wanted to push the Pi 400 harder, so we overclocked to 2.1GHz and repeated the tests. The idle temperature remained a cool 32 C, with a peak of 54 C during Stressberry.

All said and done, while it is a departure from the usual pared-back Pi experience, the 400 is a great all-arounder. We get the same Raspberry Pi experience, but with far fewer wires and setup. As a $100 package, it's an ideal gift for someone taking their first steps in coding. The awkward GPIO access and lack of camera and display ports are the only negatives that we can think of. All in all, it's the perfect Raspberry Pi for those new to the community. **–LES POUNDER**

**VERDICT**
**9**

**Raspberry Pi 400**

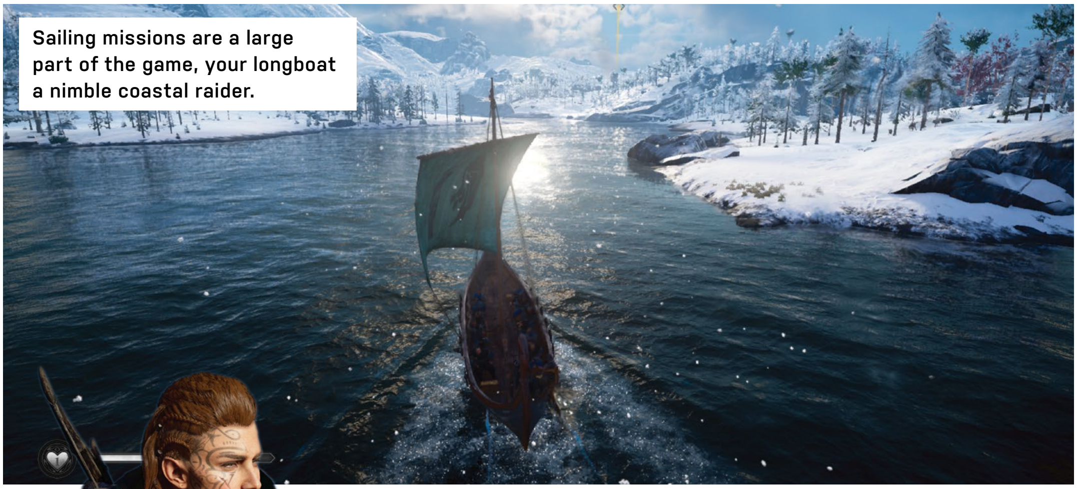
**+ SHE'S MY CHERRY PIE** Awesome package; small form factor; better performance; good price; overclocks well.

**– MUD PIE** Difficult to access certain pinouts without breakout board; no CSI or DSI connectors.

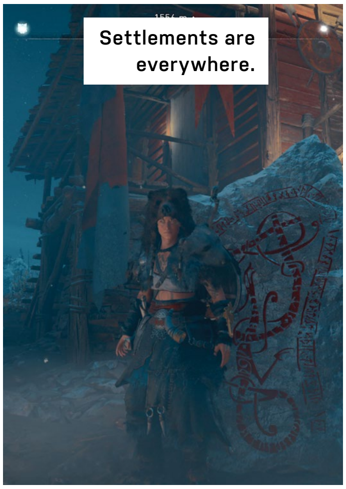
$100, www.raspberrypi.org

### SPECIFICATIONS

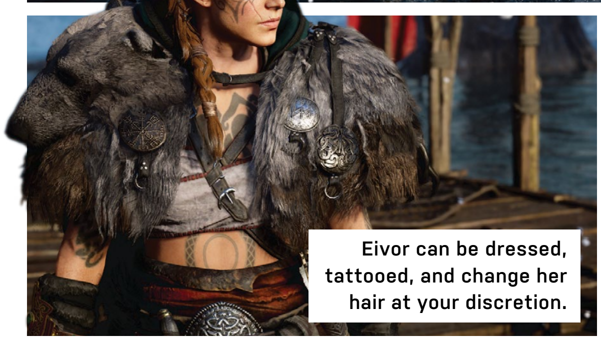
| | |
|---|---|
| **CPU** | 1.8GHz 64-bit quad-core ARM Cortex-A72 (ARM v8, BCM2711) |
| **RAM** | 4GB LPDDR4 |
| **Comms** | Bluetooth 5.0, BLE Wi-Fi dual-band 802.11b/g/n/ac |
| **Ports** | 2x USB 3.0, 1x USB 2.0, Gigabit Ethernet, 40-pin GPIO, 2x Micro HDMI (4K @ 60) |
| **Video Support** | H.265 (4K @ 60) H.264 (1080p @ 60, 1080p @ 30 encode), OpenGL ES3.0 |
| **HDD** | MicroSD card |
| **Power** | USB-C |
| **Size** | 11.0 x 4.6 x 0.7 inches |



Sailing missions are a large part of the game, your longboat a nimble coastal raider.



Settlements are everywhere.



Eivor can be dressed, tattooed, and change her hair at your discretion.

They're a pensive folk, given to staring out over the sea.

ACTION ROLE-PLAYING

# Assassin's Creed Valhalla

## A huge open world that offers runes with a view

**THE THING ABOUT** *Assassin's Creed* games these days is not so much what changes between releases, but what stays the same. *Odyssey* followed a very similar path as *Origins*, the series's rebirth into a curious action-stealth-RPG hybrid, but *Valhalla* takes the opportunity to shake things up a little, mixing it with an evocative new setting (and acting as a launch title for the powerful new consoles) to great effect.

That said, it's still an open-world Ubisoft game, which means, well, not quite what it used to. You can choose before you start playing whether to keep the constant nag of map icons trying to drag you off to find a stash of silver coins or a strange character to do a job for, or whether to explore the lands yourself, stumbling upon side quests in a more natural way. Even if you choose the former, the icons often fade away as you get really close to your target, forcing you to explore to find what you're looking for. *Origins*' and *Odyssey's* character levelling is gone, meaning NPCs don't wander around with a number floating over their heads. Your Power level is what defines you now, determined as much by your weapons and armor as the skill points you've spent. Enemies whose Power is far above yours are marked with a red skull, so you know not to start a fight you can't win.

There's still a way to proceed other than running away and grinding until you're more powerful, and it often takes the form of sneaking around and scoring headshots with a bow. You can still stealth-attack from the bushes, and an unlockable skill turns assassinations of characters you wouldn't usually be able to kill into a QTE.

Stealth, however, is much less of a theme in this iteration of the game. This fits in nicely with the Viking setting—it's the ninth century, and you play as Eivor, the son or daughter of a Norse chief, either fixing your gender at the beginning of the game or allowing it to switch between the two as it sees fit (which is less intrusive than it sounds, and actually the way Ubisoft recommends you play the story). These Vikings are not a subtle people, much more likely to run into a coastal village and set it on fire while yelling than they are to skulk in the bushes whistling until a guard comes near. For all this, they're a people of craftsmanship and poetry, driven to expand their boundaries.

Starting in Scandinavia, where Eivor gathers her crew before burning a few villages and getting stuck into a little local clan rivalry, it's not long before she sets sail for England for some boundary expanding after another local king unites Norway. Once established in the new land, you gather resources, construct a settlement, and chop enemies to death with an assortment of axes, hammers, two-handed spears, and more. Dual-wielding can be applied to any weapon, including shields and—once you've unlocked the requisite skill—two-handed implements of messy destruction. You frequently carry several of these, three bows, some spare armor, arrows, rations, a whole treasury of metal ingots, and the hides of every creature you've come across, yet are still able to run, hide, and fight. It's a videogaming mystery.

Your settlement of Ravensthorpe operates rather like Dutch's camp in *Red*

© UBISOFT MONTREAL

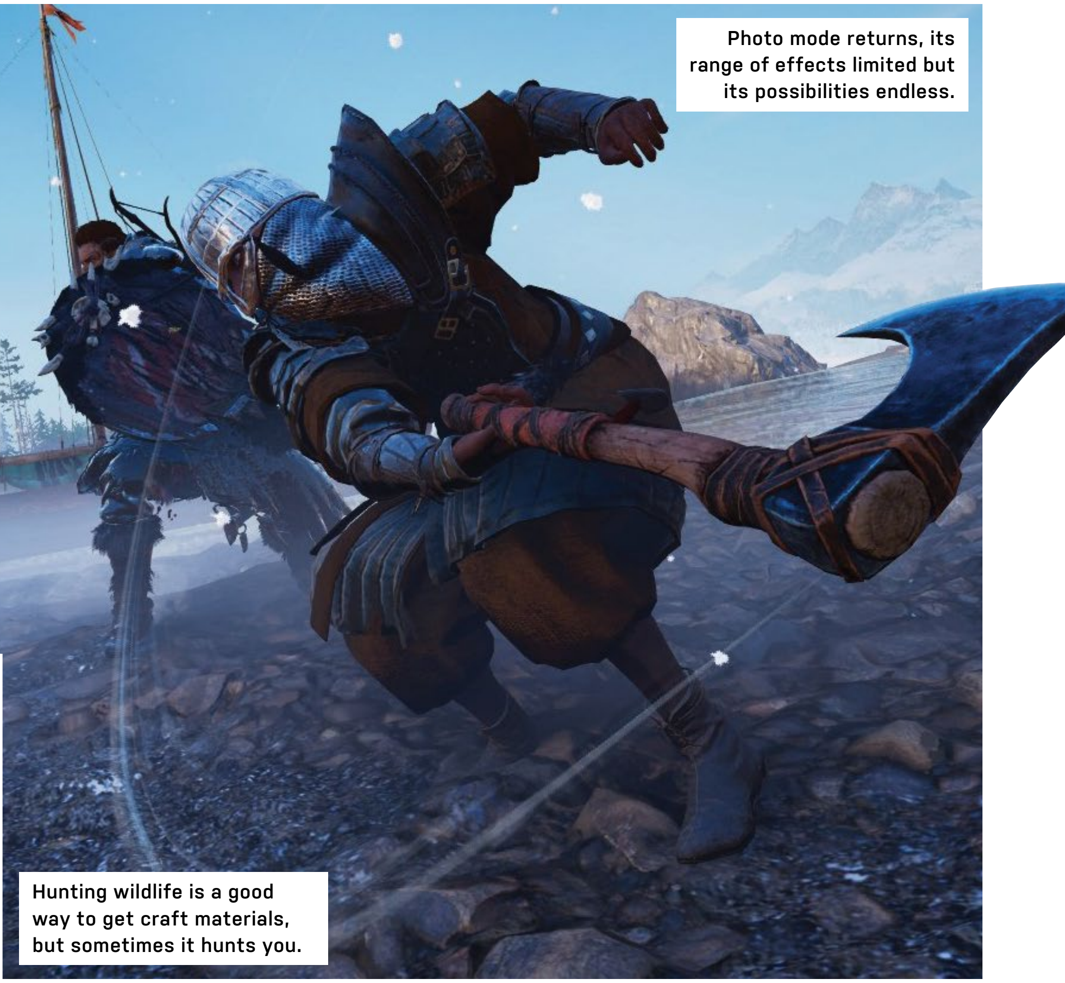


Photo mode returns, its range of effects limited but its possibilities endless.

Hunting wildlife is a good way to get craft materials, but sometimes it hunts you.

*Dead Redemption 2.* Eivor's story is very much one of uniting factions that have become splintered, and an early cutscene features weavers bringing disparate threads together into cloth. Known as Norns in Norse mythology, these women rule the destinies of men and gods. Eivor has further encounters with prophecies, gods, and monsters, but the majority of her concerns are in the mortal realm as she explores the beautiful new lands the gods have gifted her. It's a game with a hunger for processing power (we were hoping to review it on an RTX 3080, but it still hasn't arrived, so we were forced to turn the resolution down to 1080p to get a frame rate above 30fps at Ultra settings on the GTX 1070Ti), but one that repays your investment in hardware.

## TIME TRAVELING

It's also a game that takes a very long time to get going. Spend your time exploring the early Scandinavian portion of the game, a tutorial area in all but name, discovering all the hidden wealth, chasing side quests, earning skill points (we recommend seeking out the grisly stomp finishing move), and hunting down the books that give additional powers (a flurry of thrown axes? Yes please!), and you'll easily rack up 10 hours of play before you're ready to leave for England. The maps are huge, richly dotted with things to find and do, and you can waste hours playing Orlog—think *The Witcher's* Gwent—or Flyting, a sort of poetic rap battle. Run through the story missions without going off-track, however, and you'll find yourself sailing off having missed some of the game's more interesting side quests.

And, yes, all the modern-times nonsense with the Animus is still there, seemingly only to give Ubisoft the defense of "it's all a simulation" when glitches happen. No one would mind if this was removed completely. Better are the sections where you're stripped of your usual gear and placed in an unfamiliar area—in this case the bits of Canada and Greenland the Vikings knew as Vinland. Fans of *Assassin's Creed III* (there must be some) will be particularly pleased.

Each mainline *Assassin's Creed* game seems to be trying to outdo the previous one in terms of size, and *Valhalla* is surely butting up against some sort of limit to how much time players are prepared to sink into an individual title. We're almost certain to be proved wrong there, but with DLC expected by the time you read this, we wonder how people can keep up. The game is polished to a fine silver sheen and has an edge worthy of Ravensthorpe's blacksmith, its flaws reduced to mere annoyances (we're more irritated by the continued non-appearance of that graphics card). It's a saga that should remain long in the memory, and a worthy champion for the state of gaming right now. **–IAN EVENDEN**

VERDICT
9

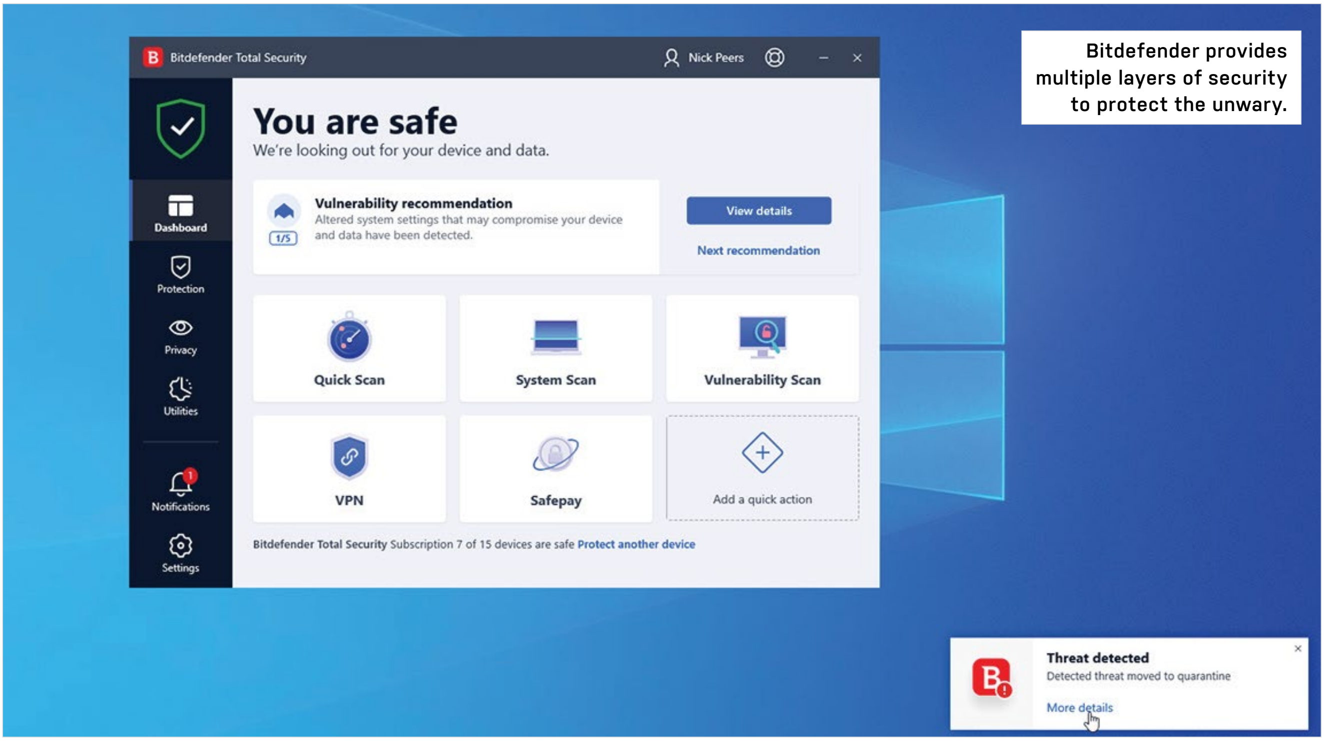
**Assassin's Creed Valhalla**

**NORSE** Enormous maps; compelling stories; rugged good looks.

**WORSE** High specs needed; slow to get started.

**RECOMMENDED SPECS** i7-6700/ Ryzen 7 1700 processor; 8GB RAM, GTX 1080/Vega 64 GPU.

$60, www.ubisoft.com, ESRB: M



You are safe

We're looking out for your device and data.

Vulnerability recommendation

Altered system settings that may compromise your device and data have been detected.

Bitdefender Total Security Subscription 7 of 15 devices are safe Protect another device

Threat detected

Detected threat moved to quarantine

Bitdefender provides multiple layers of security to protect the unwary.

# Bitdefender vs. Avira

## Does paid-for security have the edge over free?

**DOES ANYONE NEED** paid-for security software these days? Indeed, does anyone need any third-party security, given Windows now ships with a full-fledged antimalware tool in the form of Windows Security? That's the conundrum we've put to this issue's head-to-head, focusing on two products—one free (Avira Free Security) and one paid-for (Bitdefender Total Security)—to see whether you should still be paying for security in 2021. We've also taken the liberty of measuring both against Windows Security (Win 10's built-in protection) to see whether you actually need to install either.

Let's start with the most important factor: their ability to detect, block, and remove malware. The good news is that in the most recent tests (October 2020), all three scored highly across the board for protection, performance, and usability. Ironically, it was Windows Security that scored a perfect 6.0 for all three. Bitdefender also scored 6.0 for its protection, but Avira did dip slightly to 5.5.

What does this mean in real terms? All three products detected 100 percent of widespread and prevalent malware, but Avira's rates dipped to 98.9 percent when it came to blocking zero-day malware attacks. Both Bitdefender and Windows Security maintained a perfect 100 percent rating. Bitdefender's usability rating suffered compared to its rivals because its behavioral tools are a little overzealous, throwing up six false-positives in the most recent test. Finally, while all three scored perfectly in the performance stakes, a look behind the headline figures again reveals Bitdefender has a slightly heavier toll on performance—a 14 percent impact on loading websites, and 10 percent on app launch. Here Avira shines, with a lighter touch even than Windows Security.

Of course, independent lab tests are all well and good, but you wouldn't expect us to test these two products without chucking some malware samples of our own at them—within a lock-tight Win 10 virtual environment no less. Of these, only Bitdefender flagged up the malware-hosting websites as dangerous, highlighting that its protection goes above and beyond the basics. It also seemed quicker at spotting malicious downloads while in progress.

All three products react in a similar way to malware—if it attempts to execute itself, a pop-up window flags the threat and asks you to take action, typically to wipe the file or place it in quarantine. Both Avira and Bitdefender's pop-ups are clear and unequivocal, while Windows Security uses the Windows notification tool, which makes its alerts less visible.

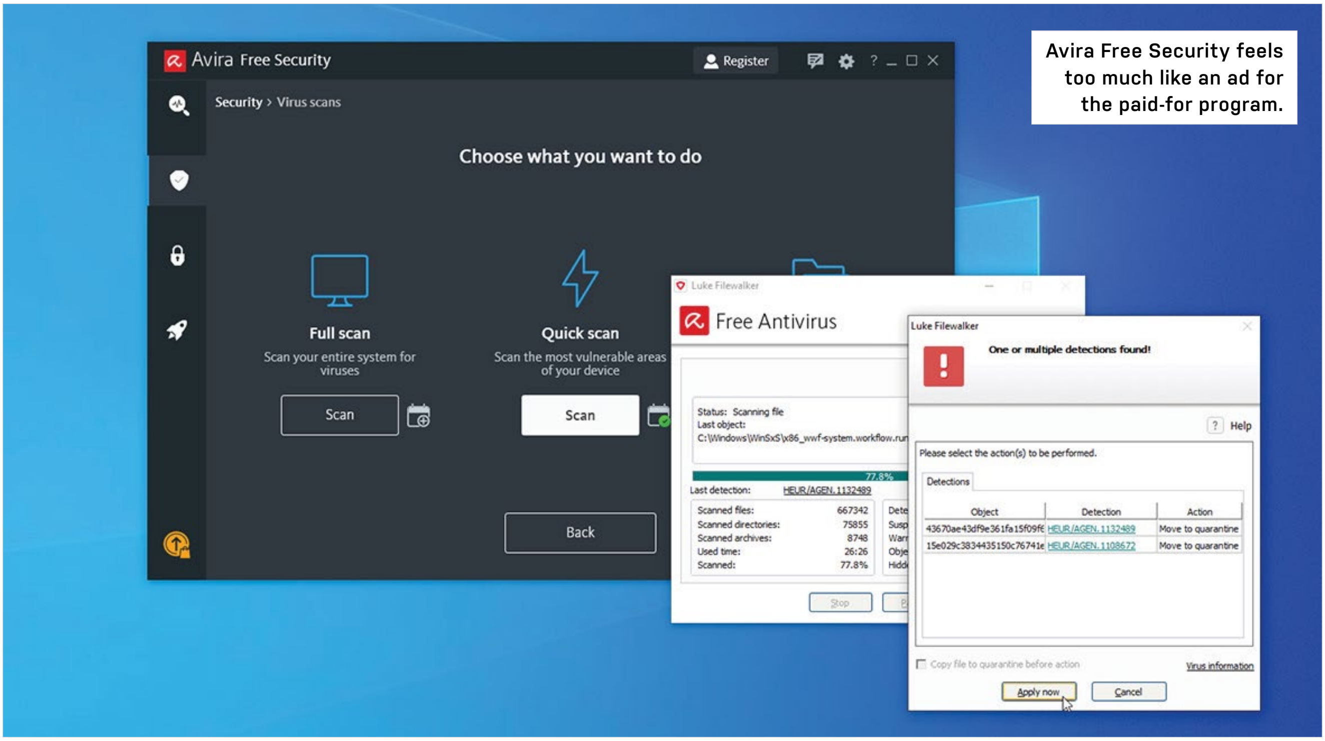
Other threats can be downloaded and left dormant on your hard drive, though–because they don't attempt to run, they remain hidden until your next scan (which is why it's important to scan downloaded files by right-clicking them), at which point they're spotted and dealt with.

Both Avira and Bitdefender identified the threat, but provided little information about it, although Avira users can click to find out more online. Windows Security offers lots of detail via its Protection History feature, reducing the need to check online. Ultimately, though, threats are flagged and dealt with when detected.

### EXTRA PROTECTION

When it comes to its user interface, Avira Free Security often feels like it's got two faces: the program's main UI is slick enough, but behind the scenes lurks Avira Antivirus, complete with its own, far less attractive, dashboard. Many functions are duplicated in the main Avira UI, and it's careful to keep the Antivirus dashboard out of sight, but you'll see its ugly features pop up when you perform scans, or it throws up an alert and you click "Details"

© BITDEFENDER



Status: Scanning file
Last object:
C:\Windows\WinSxS\x86_wwf-system.workflow.run

77.8%

Last detection: HEUR/AGEN.1132489

| | |
|---|---|
| Scanned files: | 667342 |
| Scanned directories: | 75855 |
| Scanned archives: | 8748 |
| Used time: | 26:26 |
| Scanned: | 77.8% |

Luke Filewalker

One or multiple detections found!

Please select the action(s) to be performed.

| Object | Detection | Action |
|---|---|---|
| 43670ae43df9e361fa15f09f6 | HEUR/AGEN.1132489 | Move to quarantine |
| 15e029c3834435150c76741e | HEUR/AGEN.1108672 | Move to quarantine |

☐ Copy file to quarantine before action

Avira Free Security feels too much like an ad for the paid-for program.

© AVIRA

to find yourself within a completely separate UI.

Avira's security is so basic it's eclipsed by Windows Security in key areas, such as protection from ransomware. Most of its options simply point you toward the paid-for product. What you do get in addition to its core antimalware protection is a smart scan, which highlights areas of concern, namely privacy, performance, viruses, outdated apps, and network threats. After the scan, you can review its findings, but when you click "Fix Issues," very little actually gets fixed—and of those, we're never convinced by Registry cleaners.

What Avira wants you to do is unlock its Prime subscription, which covers up to 25 devices for $9.99 a month or $99.99 a year. Ultimately, the free product offers little to recommend it over Windows Security.

Bitdefender easily eclipses both products, however—but then you are paying for the privilege. Look out for deals on its top-of-the-line Family Pack, which covers 15 devices across your family, and can be regularly found for under $50 a year (indeed, you can sniff out two-year deals for under $40).

Bitdefender is centered around its Dashboard, which while not exactly eye-catching, does at least provide reasonably intuitive access to its many and varied components. That said, there's so much tucked away that we can't help but feel it would benefit from a quick-find tool along similar lines as Windows 10's own Settings utility. One handy shortcut is the customizable quick actions, which allow you to pin frequently used tools to the main Dashboard.

As a paid-for product, everything you see in Bitdefender is available—split into three logical sections: Protection, Privacy, and Utilities. Additional protections include its own firewall, online threat prevention—which, among other things, blocks access to dangerous websites—as well as a built-in email scanner.

Bitdefender's ransomware protection has undergone a revolution with the new Ransomware Remediation. This identifies attempts by ransomware to encrypt files, creating a secure backup of any files that are targeted, restoring them only after it's dealt with the infection. It's not enabled by default, but Bitdefender prompts you after installation and again via its Dashboard to switch it on. It suggests other hidden parts of the suite as time goes on, too.

There's also a vulnerability scan, with one-click fixes for outdated apps, missing updates, and insecure system settings, plus an antispam module that supports Thunderbird, Outlook, and more.

The Privacy section's highlights include SafePay for secure online transactions using a sandboxed browser, password manager, video and audio protection (blocking access to webcams and mics), antitracker, and parental advisor. The final section—Utilities—includes a file shredder and antitheft component, which whisks you off to your online Bitdefender account and provides remote tools for locating (via an audio alert), locking, and wiping your protected devices. Things are rounded off with a few performance-enhancing tools. You can source free versions of many of these, but having them under one roof is convenient.

If you've not worked it out, our choice is Bitdefender. Avira Free Security feels superfluous next to Windows Security's excellent levels of protection. Bitdefender, on the other hand, combines a renowned protection engine with loads of useful (but optional) components that enable you to cover your PC in extra layers of protection from today's fast-evolving threats. If you don't trust yourself to be extra careful when you're online, Bitdefender should have your back. **–NICK PEERS**

**VERDICT**

**9**

**Bitdefender 25.0**

**FORT KNOX** Rock-solid; loads of extra protection as standard.

**FORT WILLIAM HENRY** Can be over-zealous; some tools difficult to find; pricey.

**RECOMMENDED SPECS** Intel Core CPU, 4GB RAM, 2.5GB hard drive space, Win 10.

$120 per year, www.bitdefender.com

**VERDICT**

**7**

**Avira Free Security**

**CHAMP** Won't slow you down; adequate basic protection; free.

**CHUMP** Most components require upgrade to paid tier; some zero-day threats evade it.

**RECOMMENDED SPECS** Intel Core CPU, 4GB RAM, 2GB hard drive space, Win 10.

$Free, www.avira.com

# LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Undervolting
> Budget Builds
> Journo Picks

## Connecting Mice

Hey Zak, I love your work. I was just thinking back to your article on the Corsair Ironclaw. Did you end up using it for a long period of time? I was thinking about grabbing one, but I've read that people have had connectivity issues with it in the past, and wanted to see if you'd encountered that as well. Thanks!

**–Kyle S**

**EDITOR, ZAK STOREY, RESPONDS:** Hi Kyle, good to speak to you. Wow, it's been a while since I checked that out. I've had a go with a fair few wireless mice since then, and can report that I've had very few issues with them. It seems the tech and software have improved quite dramatically over the last few years. I did use the Ironclaw for a fair amount of time, but sadly only in wired mode. I prefer a USB connection and a heavier mouse for my day-to-day work, so having one with a chunky battery in it hooked up via a cable is ideal for me. That said, I didn't have too much of an issue on the connectivity front; in fact, I even managed to get it connected to my phone, which was fun, if not a little weird. Nothing quite like selecting apps using a mouse pointer—genuinely didn't even know that it was a thing.

Every now and then it did take a while to pick up on desktop over that 2.4GHz wireless connection, but that was a long time ago now, and I'm assuming Corsair has updated the firmware since then and given it a bit of a fresh kick in the rear as far as connectivity lag is concerned.

Apart from that, it's a good piece of gear. I've actually gone back to the Glaive RGB Pro recently for my daily driver, purely because it follows a similar design ethos, and I like the hot-swappable sides. That's neither here nor there, though, as it's very much wired.

## Understand Undervolts

Hi Zak, I see you often recommend undervolting a processor to get the most out of it. Can you explain why that's a good idea, given that it goes against the manufacturer's guidelines? It always seems like a particularly crazy idea to me.

**–B. Garner**

**EDITOR, ZAK STOREY RESPONDS:** I love undervolting. It's a bit bizarre but the potential for overclocking has become very tightly constricted over the last few years, as manufacturers constantly strive for more performance, so undervolting seems to be picking up steam as being a more interesting hobby, especially if you like tinkering with things. Strangely enough, trying to overclock these days often leads to less performance, not more.

Undervolting basically comes down to the silicon lottery, plus some other factors. Intel and AMD set out specific operating parameters for their processors. These are generated on an average basis across all of their processors, as opposed to each individual chip. These operating parameters are then implemented into the motherboard BIOSes, and they effectively tell the system how much voltage the processor should receive, at which temperature to throttle at, what clock speed to run at, and so on. There have been a lot of tools introduced, both at a software and firmware level, in the last few years that have improved performance via auto-overclocking, however very little has been done with regard to efficiency or undervolting.

The thing is, because all processors are different, much of the time these stock parameters are actually very generous. Intel and AMD need to make sure that their processors work at all times, under all circumstances. So if the end user has an awful power supply, or an OEM motherboard with four power phases, the processor still needs to function at a reasonable level. Because we're enthusiasts, those parameters aren't quite as fair on us, so you end up with a processor that is quite a lot hotter than it needs to be in its day-to-day operation. However, most AIB motherboard manufacturers just ignore that, and push more volts in anyway, to improve

↘ submit your questions to: comments@maximumpc.com performance and boost clock speeds, and you end up footing the bill in more heat.

So, what undervolting basically looks at is this scenario, where you're happy with the performance at stock, but you just want it a bit cooler. The biggest benefit to that is that you can reduce noise. If you have a cooler chip, your fans don't have to spin as fast. On top of that, your office won't get as hot, your other components won't get as hot, and you can do ridiculous things like cool a Core i5-10600K off a single 92mm CPU heatsink, like I did with the Hydra.

In a similar way as overclocking, you need to take it slowly, and the overall principle is the same. Do it in the BIOS, use an offset voltage, and slowly lower the voltage (0.02V at a time), until you reach a temperature you're content with. You will reach a point where system instability kicks in, as it would when overvolting to attempt a standard overclock.

## Budget Isn't Budget

Hi *Maximum PC* team, love the work, but I've gotta say, I don't quite have the same amount of money as you guys. Even the budget build is way too expensive for me—what would you recommend? **–Luke Smith**

**EDITOR, ZAK STOREY, RESPONDS:** Hi Luke, you bring up a good point. I think the reality is, our blueprints aren't ever going to check all the boxes for everyone. They're really about recommending a basic platform from which you can pull some things and change others to better suit your needs. Obviously, the builds are tailored toward gaming. Each one has a GPU, each one has a super-quick SSD, plus additional storage, and that basically just scales up. They're all effective at performing various tasks, no matter what, but there are ways you can shave a bit off the price tag if you're not into gaming, or you just want to save some money.

I know a lot of folk recommend eBay and second-hand parts. That is one solution, but it can be a little tricky in practice. It's difficult to know for sure who you're buying from, and what that product has been doing in its lifetime. As an example, when I first started at *Maximum PC,* part of the reason I got the job was because I managed to overclock an Intel Core i5-2500K to 5.4GHz on a single 120mm AIO in an ITX chassis. That chip was incredible—it was like the top 5 percent of Core i5s in the world at the time. But, by the time I was done with it, it struggled to hit 5.1GHz on a good day. I ended up giving it to a friend, who popped it in a liquid-cooled machine that ended up dying a year later. But it's one of those things—you just don't know what a part has been through, especially with cryptomining on the rise again (thanks, Bitcoin).

But that's not to say it's impossible. I did have a build planned for this issue until COVID struck me down, which basically was a super-budget build. It was the cheapest possible system I could put together, with an SSD, 8GB of DDR4, and a Core i3-10100 (ain't it weird Intel is now the value option?). That's now going to be in the next issue, so if you hold on for a bit, we can show you the ins and outs of how to put that together. In the meantime, it should look something like this: https://pcpartpicker.com/list/r8qgrr. That's a seriously cool build: Four cores, eight threads, 8GB of DDR4, and a fairly snappy 120GB SSD. If you wanted a decent office PC, or a good base for a 1080p gaming rig, this would be a great place to start. Pop a graphics card in there and you'd be ready to roll.

**[NOW ONLINE]**

## CYBERPUNK 2077 CPU SCALING

*Cyberpunk 2077* is the most hotly anticipated game in recent history, but it has proven to be punishing for even the most well-equipped PCs. We set out to test the new game with a wide range of the best CPUs on the market to determine which processors provide the best performance in a large selection of resolutions. We've tested AMD's Ryzen 9, 7, 5, and 3 processors across several generations, along with Intel's Core i9, i7, i5, and i3 processors as well.

Read the full article here: http://bit.ly/CP2077Scale

© CD PROJEKT RED

## What Would You Buy?

I've always wondered, if you weren't in tech, but had all the knowledge, what would you spend on a gaming PC? **–R. Lower**

**EDITOR, ZAK STOREY, RESPONDS:** Great minds think alike, because this is something I've given some thought to. If I weren't a tech journalist, life would be very different. I think the first thing I'd aim to do is target a resolution for my gaming habits. I'd still like productivity and screens, so that would be my first port of call. Superwides are my passion when it comes to screens, so I'd try to find a decent one for cheap. Viotek's GN34CW looks interesting; it's the cheapest 3440x1440 and has a VA panel, but I've no idea if it's any good. $340 for a monitor would be about right, I think.

I wouldn't want to spend more than $1,600 on the build itself. Maybe something like this: https://pcpartpicker.com/list/WPqgrr. There's a few choice picks there, and stuff I know I'd be upgrading in the future. Power supply cables would be one of them, and doubling up that memory would be an early change. I'm actually really curious about how the AMD Radeon RX series will play out with Ryzen processors and their shared smart memory cache thing. Plus, I've always been a bit of a sucker for the underdog generally. Whether that's in sports, fights, or GPUs. So, yeah, the 6800 would be a prime choice for 1440p gaming, coupled with the six-core Ryzen 5 5600X to give me a bit of versatility, plenty of headroom on the PSU, and some dishy storage, too—then it would be a solid rig. I'll be honest, the AIO is also massively overkill, and possibly something I'd skip in the early days. ⏻

# THE BUILDS

## BUDGET

**WE ARE STILL** in the throes of supply shortages right now. And you can see that across both our budget builds. We've managed to claw back some costs, but sadly GPU prices on the low-end are still at unmanageable levels, and stock is precarious. To that end we've swapped to the MSI Radeon RX 5500 XT Gaming X for our AMD system, and the GeForce GTX 1650 Super OC on Intel. Both are roughly the same price, and perform similarly—the 1650 Super edges out the 5500 XT for performance and is slightly cheaper too, although both are floating above their RRPs annoyingly.

We've also had to swap out our Intel processor from the Core i5-10500 to the Core i3-10100. This saves us a ton of cash, bringing that processor price down to just $114. It's still slightly more costly than the AMD Ryzen 3 3100 in our Red build, but it does perform ever so slightly better, and of course comes with Hyper-Threading, so you still got those four cores and eight threads.

Memory is a bit of a sticking point for this build, but we've kept the 16GB in play. Theoretically you could possibly get away with 8GB of DDR4 if you really need to shave off some cost, but it's only about $15-20 cheaper than picking up a 16GB kit, and that extra memory headroom will do a ton of good. One place you could save money on this build would be by dropping the secondary storage, saving you $40 on each build. Alternatively, with the Intel setup you could take the GPU out of the equation entirely and bring the price down to just $493. Sadly that's not possible with the AMD system as the Ryzen 3 3100 lacks integrated graphics.

It's a tricky time to be a PC enthusiast, but unfortunately there's not much we can do about it. It's a snowball effect: More people are at home on their PCs, and as always with new launches production is a bit slow, and those two factors, combined with some economic ones, are having a significant impact across the entire sector, from consoles to phones to PC parts.

### AMD INGREDIENTS

| PART | | PRICE |
|---|---|---|
| Case | Corsair 4000D Airflow | $80 |
| PSU | 450W EVGA 450 BR 80+ Bronze **NEW** | $42 |
| Mobo | Gigabyte B450M DS3H V2 **NEW** | $65 |
| CPU | AMD Ryzen 3 3100 | $100 |
| GPU | MSI Radeon RX 5500 XT Gaming X **NEW** | $210 |
| RAM | 16GB (2 x 8GB) ADATA XPG Z1 @ 3000 MHz **NEW** | $55 |
| SSD | 250GB Samsung 980 Pro M.2 PCIe 4.0 | $77 |
| HDD | 1TB Western Digital RE4 3.5-inch HDD **NEW** | $39 |
| OS | Windows 10 Home 64-bit OEM | $25 |
| **Approximate Price:** | | **$693** |

### INTEL INGREDIENTS

| PART | | PRICE |
|---|---|---|
| Case | Corsair 4000D Airflow | $80 |
| PSU | 450W Gigabyte GP-450B 80+ Bronze | $45 |
| Mobo | MSI B460M-A PRO Micro-ATX **NEW** | $75 |
| CPU | Intel Core i3-10100 **NEW** | $114 |
| GPU | Gigabyte GeForce GTX 1650 Super OC **NEW** | $202 |
| RAM | 16GB (2 x 8GB) ADATA XPG Z1 DDR4 @ 3000 MHz | $55 |
| SSD | 500GB Samsung 970 Evo M.2 PCIe 3.0 SSD | $60 |
| HDD | 1TB Western Digital RE4 3.5-inch HDD **NEW** | $39 |
| OS | Windows 10 Home 64-bit OEM | $25 |
| **Approximate Price:** | | **$695** |

## MID-RANGE

**AS FOR OUR MID-RANGE BUILDS**, things are starting to look a bit better. On the whole we haven't been forced to make many changes, and we've actually managed to drop the price of both systems.

The big changes in the AMD build are the new power supply—a snazzy RGB 650W Corsair affair—new cooler (this editor's personal favorite), the HS60 120mm AIO—again from Corsair (check out the letter on undervolting in our comments section on PG 94), and some serious shake-ups to storage. Amazingly GPU prices are actually holding steady this time around, so there's less worry there. However, AMD's latest Ryzen 5000 series are still MIA as far as the tech world is concerned. If you can get one, jump on it. The X570-Plus will support it, and the improved single-core performance is not to be sniffed at.

For our Intel system, the changes have been less dramatic. We're still holding onto that Core i7-10700 processor, which has seen a comfortable $5 drop in price, but we've also swapped out a few of the other components, including the GPU and the motherboard. The Aorus Elite AC is a fantastic little number for any LGA1200 chip, and has some impressive connectivity for the price. We've also managed to snag this excellent MSI GeForce GTX 1660 Super 6GB Ventus XS OC (who comes up with these names?), which is nearly $90 cheaper than our AMD equivalent, and performs only slightly worse, which in our eyes is a win. Either card is a good choice for 1440p gaming, and you should be able to achieve a comfortable 45-60fps in most titles on ultra.

As for memory, we're still sticking with 16GB across the board here, although it's that gray area where you might be better off opting for a 32GB kit instead. Pair all this together with that extra RAM and you'll find yourself with a fantastic video-editing and photo-editing system, ideal for any hobbyist or enthusiast keen on getting their face out into the digital world.

### AMD INGREDIENTS

| PART | | PRICE |
|---|---|---|
| Case | Lian Li PC011-Dynamic | $140 |
| PSU | 650W Corsair CX650F RGB 80+ Bronze **NEW** | $70 |
| Mobo | Asus TUF Gaming X570-Plus | $165 |
| CPU | AMD Ryzen 5 3600 | $200 |
| Cooler | Corsair HS60 120mm AIO **NEW** | $50 |
| GPU | MSI Radeon RX 5700 Gaming X 8GB | $394 |
| RAM | 16GB (2 x 8GB) G.Skills Ripjaws V @ 3600 **NEW** | $69 |
| SSD | 500GB Sabrent Rocket 4.0 M.2 PCIe 4.0 **NEW** | $90 |
| HDD | 1TB Western Digital RE4 3.5-inch HDD **NEW** | $40 |
| OS | Windows 10 Home 64-bit OEM | $25 |
| **Approximate Price:** | | **$1,243** |

### INTEL INGREDIENTS

| PART | | PRICE |
|---|---|---|
| Case | Lian Li PC011-Dynamic | $140 |
| PSU | 650W Cooler Master MasterWatt 650 | $85 |
| Mobo | Gigabyte Z490 Aorus Elite AC **NEW** | $170 |
| CPU | Intel Core i7-10700 | $320 |
| Cooler | Cooler Master Masterliquid ML240L AIO | $70 |
| GPU | MSI GeForce GTX 1660 Super 6GB Ventus XS OC **NEW** | $301 |
| RAM | 16GB (2 x 8GB) Crucial Ballistix @ 3200 **NEW** | $65 |
| SSD | 500GB WD Black SN750 M.2 PCIe 3.0 | $65 |
| HDD | 1TB Western Digital RE4 3.5-inch HDD **NEW** | $40 |
| OS | Windows 10 Home 64-bit OEM | $25 |
| **Approximate Price:** | | **$1,281** |

**IT'S HAPPENING PEOPLE**, you can finally pre-order an AMD Ryzen 9 5900X at a respectable price! OK, so it might not be in stock as we write this (hopefully it will be as you're reading it), but the impeccable 5900X is now available for pre-order across a number of major e-tailers, and we've added it to the Turbo AMD build, swapping out the somewhat aged 3950X. It might not have the 16 cores that its older brother has, but with a new cache design, far superior single-core performance, and access to some smart cache graphics systems, it's a kick-ass chip that can do it all, and still keep cool. It's also saved us nearly $300, so losing those four extra cores doesn't seem like that big of a deal here.

We've also swapped out the motherboard, power supply (for the more modern RM version as opposed to the RMx), and the memory to make this a far cleaner system. And last but not least, we've found an Nvidia GeForce RTX 3080 10GB that you can pre-order for its retail price as well. Incredible! And as an added bonus you get to own a card with the world's longest product name. In fact both systems are sporting our PNY GPU of choice this time around—we did try to source an AMD Radeon RX 6000-series card, but the cheapest one we could find was an RX 6800 at $1,500, almost three times its retail price.

Over to our Intel system, and the changes have been far more subdued (mostly due to the fact that Intel isn't suffering from quite the same level of stock shortages as AMD). We're still keeping hold of the Core i9-10900K, but have switched out the motherboard for an Asus PRIME Z490-A. It's a slicker, professional-oriented budget Z490 board, and it's an awesome pick.

As for storage, we've dropped down from the WD Red Pro HDD to just the standard Red, saving about $10; for what we're doing here, this should be fine. And lastly our Intel system has moved over to the Corsair MP400 1TB M.2 PCIe 3.0 SSD—welcome to the world of what QLC should've been to begin with.

## AMD INGREDIENTS

| PART | | PRICE |
|---|---|---|
| Case | Phanteks Enthoo Pro 2 Tempered Glass | $147 |
| PSU | 750W Corsair RM750 80+ Gold **NEW** | $125 |
| Mobo | MSI MAG X570 TOMAHAWK WIFI **NEW** | $220 |
| CPU | AMD Ryzen 9 5900X **NEW** | $550 |
| Cooler | Corsair iCUE H150i Elite Capellix 360mm AIO | $170 |
| GPU | PNY GeForce RTX 3080 10GB XLR8 Gaming EPIC-X RGB **NEW** | $750 |
| RAM | 32GB (2 x 16GB) G.Skill Trident Z Neo @ 3600 **NEW** | $160 |
| SSD | 1TB Gigabyte Aorus Gen4 M.2 PCIe 4.0 | $160 |
| HDD | 6TB Western Digital Red HDD **NEW** | $126 |
| OS | Windows 10 Home 64-bit OEM | $25 |
| **Approximate Price:** | | **$2,433** |

## INTEL INGREDIENTS

| PART | | PRICE |
|---|---|---|
| Case | Phanteks Enthoo Pro 2 Tempered Glass | $147 |
| PSU | 750W be quiet! Straight Power 11 80+ Gold **NEW** | $140 |
| Mobo | Asus PRIME Z490-A **NEW** | $210 |
| CPU | Intel Core i9-10900K | $517 |
| Cooler | NZXT Kraken X73 360mm | $180 |
| GPU | PNY GeForce RTX 3080 10GB XLR8 Gaming EPIC-X RGB **NEW** | $750 |
| RAM | 32GB (2 x 16GB) Corsair Vengeance RGB Pro @ 3600MT/s | $168 |
| SSD | 1TB Corsair MP400 M.2 PCIe 3.0 SSD **NEW** | $115 |
| HDD | 6TB Western Digital Red HDD **NEW** | $126 |
| OS | Windows 10 Home 64-bit OEM | $25 |
| **Approximate Price:** | | **$2,378** |

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